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# Individual Compensation and Firm Performance: The Economics of Team Incentives

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# INDIVIDUAL COMPENSATION AND FIRM PERFORMANCE: THE ECONOMICS OF TEAM INCENTIVES

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# INDIVIDUAL COMPENSATION AND FIRM PERFORMANCE: THE ECONOMICS OF TEAM INCENTIVES

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**Abstract**

This paper analyzes the properties of a simple performance contract that bases individual compensation on the performance of the firm. The contract is potentially important if individual performance is expensive to measure. With risk neutrality and unobserved individual performances, the team performance contract pays each worker the product price for each unit of the team's output, and jobs sell for a positive price. This contract's strong incentives generate the first-best allocation of resources.

High quality signals of individual performance, risk aversion, large firm size, sabotage, collusion, and adverse selection cast this potentially powerful incentive contract in a minor role in the labor market. However, the optimal contract retains the principal feature of linking individual pay and firm performance. The strength of the relationship between individual pay and firm performance is predicted to vary with these six features.

The model is applied to understand the weak relationship between the compensation of top executives and firm performance.

*Keywords*: Incentives, Teams, Executive Compensation

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# Individual Compensation and Firm Performance: The Economics of Team Incentives

## I. Introduction

The fortunes of workers depend on the fortunes of their firms. Counter to the textbook competitive model of the labor market, a worker's wage tends to vary with his employer's successes and failures. Thus an individual's compensation is related to the performance of his co-workers and other factors of production.

In this paper, I characterize a simple compensation contract that bases individual pay on the performance of the firm or the output of the team. As such, my analysis of the team performance contract draws from the influential work of Holmstrom (1982) on incentives in teams. (Also see Alchian and Demsetz (1972), Groves (1973), and McAfee and McMillan (1991).) In addition, analysis of team incentives relates to the empirical literature on executive compensation (e.g., Jensen and Murphy 1990), which links the compensation of a CEO to the profitability or value of the firm.

The team performance contract is a potentially important mechanism for generating incentives if individual performance is difficult to measure. The simplest team performance contract pays each worker the total revenue of the firm. This contract generates the right marginal incentives, because each worker receives 100 percent of the benefit and bears 100 percent of the cost of his actions; and it economizes on the cost of measuring performance, because individual output need not be observed. By setting the level of pay, which is controlled by the contract's intercept, this contract can also be competitive. Each job in effect sells for the expected value of the sum of the $n-1$ other workers' outputs. Thus the simplest team performance contract is competitive and provides strong incentives. Indeed, it is the optimal linear contract if workers are risk neutral and individual performance is costly to observe. Unlike tournaments and other compensation contracts that base pay on relative performance, team incentives also provide incentives for cooperation among workers.

The potential applications of the simplest team performance contract are numerous and varied. In the context of the labor market, workers from the mail room to the board

room could be paid this way. For instance, at General Electric, which employs nearly 300,000 people and generates about $55 billion in revenues annually, each worker would be paid General Electric's annual revenues and each job would sell for about $25,000 less than $55 billion. With such a compensation structure, General Electric would eliminate all the costs associated with supervision and performance evaluation.

A second example confronts the problem of splitting the check at a restaurant. Each of five diners would spend on average $15 for dinner if separate checks were used, but separate checks are costly; and allocating the group's expenses to individuals is frequently a nuisance. Thus a competitive restaurant offers the group a $300 credit, but requires each diner to pay the whole check. Since the marginal incentives are correct, the check totals $75 on average and the restaurant's gross revenue from the table averages $375 ( $= 5 \times \$75$). After the credit, each person pays $15 on average.

The third example applies team incentives to the problem of pollution abatement. Farmers along a river fertilize their lands, and the toxic chemicals seep into the river, which contaminates the water downstream. With many farms and farmers, it would be quite costly to allocate the damages to particular farms. However, if *each* farmer were charged for *all* the damage to the river, the correct incentives to fertilize would obtain. Property taxes to farms along the river could be lowered so that the net revenue from the pollution tax equaled the cost from contaminating the river.

As a fourth example, consider applying the team performance contract on a global scale. Each person would be compensated on the basis of the value of world output, and a rather large head tax would be levied. Shirking and perhaps war would vanish from the planet as each person would behave to maximize the value of world output net of his own cost of effort. By compensating on the basis of collective performance, distribution is egalitarian. Could this compensation scheme deliver the communist ideal, "from each according to his ability, to each according to his need"? Certainly not.

Despite the numerous and varied potential applications, the team performance

contract in its simplest form does not appear to exist in practice anywhere. Why not? While most applied research in contract theory seeks to understand *why* a particular form of organization or set of institutions exists, one purpose of this paper is to analyze *why not.* Why not team incentives?

Holmstrom (1982, 328) conjectured that borrowing or bankruptcy constraints would render the simplest team performance contract infeasible. But to affect equilibrium compensation, the constraint must be binding. For instance, a worker would draw his savings down to zero and borrow to the limit to buy a job. That the labor market bears no resemblance to this prediction suggests that financial market imperfections—which might exist—do not account for the absence of team incentive contracts.

Alternatively, my analysis highlights the effects of risk aversion, sabotage, collusion, and adverse selection in undermining team incentives. I present the analysis in three sections. In section II, I construct a more general team performance contract. The generalization allows pay to depend on a signal of personal performance, as well as on the output of the firm, and allows workers to be risk averse. The optimal contract includes positive team incentives, but they are generally substantially weaker than those of the simplest team performance contract from above. The link between individual compensation and firm performance is predicted to be stronger the smaller is the firm and the noisier is the signal of personal performance.

The link between individual compensation and firm performance also depends on richer forms of malfeasance. In section III, I enrich the contracting environment to examine the effects of sabotage, collusion, and adverse selection in weakening the link between individual pay and firm performance. Thus my analysis reflects the renewed interest in the problems of strong incentives (Milgrom 1988; Lazear 1989; Fama 1991; Holmstrom and Milgrom 1991; Gibbons and Murphy 1992; and Baker 1992).

First, consider the effect of sabotage in the context of a football team. For simplicity, assume the head coach is the owner; the players are his agents. Since the coach receives the

revenue from the game once, but must pay it out 40 times (once to each player) under the team performance contract, he prefers lower realizations of output. He likes his team to lose! Since the coach has some control, he sabotages the game by calling bad and untimely plays, benching his best players, letting the equipment deteriorate, and neglecting the travel arrangements. In this environment, the optimal contract must respond to the incentives of the principal as an agent (Eswaran and Kotwal 1984).

Second, consider the effect of collusion in the context of the check-splitting example. If the five patrons of the restaurant collude to limit each person to a $12 meal, then each pays the total check of $60. Combined the five pay $300, which is exactly the credit. On net, each person receives a free meal if the collusion works. This illustrates the basic result of collusion among agents in a team performance contract: workers are better off if they all work excessively.

Third, the team performance contract generates adverse selection. If some workers are more productive than others in ways that are not observable to firms—so fully contingent prices are not possible—the best workers would sort into firms that offer only personal performance pay. A firm offering team incentives would attract only the lemons.

For each of these three extensions, I analyze how the employer and workers respond to the potential problem by choosing the optimal parameters of the team performance contract. Team incentives survive, but the simplest team performance contract is quite sensitive to these richer forms of malfeasance. Yet sabotage and collusion, like borrowing constraints, are not a problem unless workers buy their jobs. Since they do not, adverse selection emerges as the binding problem.

In section IV, the models are applied to the evidence on performance incentives in executive compensation. With noisy personal performance evaluation, the model naturally fits the magnitude of estimated team incentives, as well as the level of executive compensation; and the implied incentives are fairly strong. However, the model underpredicts the ratio of team to personal incentives.

## II. Linear Team Performance Contracts

This section characterizes a linear contract that conditions pay on an error-ridden measure of individual performance and an error-free measure of the firm's output. The development begins by specifying the environment: the $n$ workers' preferences, the firm's production technology, and the feasible contracts.

*Environment*

The $n$ identical workers are risk averse. Worker $i$'s preferences over compensation $w_i$—which equals consumption—and effort $e_i$ are summarized by a common quasi-linear utility function.

$$u_i = U[w_i - C(e_i)] \tag{1}$$

for all $i$, with $U' > 0$, $U'' \leq 0$; and the cost of effort function $C(\cdot)$ satisfies $C' \geq 0$, $C'(0) = 0$, and $C'' > 0$. With quasi-linear preferences, effort is a borderline inferior commodity; thus the analysis abstracts from income effects.

The firm, which is operated by a risk neutral principal, employs its $n$ workers to produce $Q$ units of output. The firm sells the output in the product market at price $p$ per unit. Production, which is additive across workers, is also additive in effort $e_i$ and a random disturbance $\epsilon_i$. With $q_i$ denoting worker $i$'s output,

$$q_i = e_i + \epsilon_i, \tag{2a}$$

$$Q = \sum_{i=1}^{n} (e_i + \epsilon_i). \tag{2b}$$

By restricting production to the additive form, the analysis relies on risk sharing and incentives to rationalize the existence of the firm.

The random production disturbance is assumed to be independently and identically

distributed (i.i.d.) with mean zero and variance $\sigma^2$; its density function is denoted $f(\epsilon_i)$. Since the employer is risk neutral, its objective is to maximize expected profit,

$$\pi = E\Big[\sum_{i=1}^{n}(pq_i - w_i)\Big] = \sum_{i=1}^{n}\Big(pe_i - E[w_i]\Big). \tag{3}$$

This specification of preferences and production technology generates familiar results for the first-best allocations, the Pareto-optimal allocations in the absence of informational constraints. The first-best solution allocates effort such that $C'(e_i) = p$ for all $i$, and the employer fully insures each worker against fluctuations in the wage $w_i$. The first-best level of effort $e_0$ is independent of the size of the firm and the level of pay.

To introduce the agency relationship, I follow the literature in assuming that the employer does not observe the workers' efforts $e = (e_1,\ldots, e_n)$. The employer does observe total output $Q$; also the employer observes a noisy signal $x_i$ of individual performance $q_i$: $x_i \equiv q_i + \phi_i = e_i + \epsilon_i + \phi_i$, with $\phi_i$ an independently and identically distributed measurement error term with zero mean and variance $\sigma_\phi^2$. Neither the employer nor the workers observes the production disturbances $\epsilon = (\epsilon_1,\ldots, \epsilon_n)$ or the measurement errors $\phi = (\phi_1,\ldots, \phi_n)$. Consequently, the employer and workers can write contracts that condition on the signal $x_i$ and total output $Q$. I restrict the analysis to linear performance contracts.[1]

$$w_i = \alpha + \beta x_i + \gamma Q, \tag{4a}$$

$$\mathrm{E}[w_i] = \alpha + \beta e_i + \gamma \sum_{j=1}^{n} e_j, \tag{4b}$$

where $\alpha$ is base pay (which might be negative), $\beta$ is the personal performance parameter, and $\gamma$ is the team performance parameter.

The $n$ workers are employed in a competitive labor market. Competition among firms requires that the representative firm compensates each worker such that expected utility

[1]Rather than imposing linearity, Holmstrom and Milgrom (1987) use time aggregation to generate compensation schedules that are linear.

equals a reservation level $\overline{u}$.[2] Consequently, an optimal contract is a quadruple $\{\alpha^*, \beta^*, \gamma^*, e^*\}$ that maximizes expected profit subject to each worker's reservation utility and incentive compatibility constraints.

*Agent's Problem*

Each incentive compatibility constraint is the solution to the following problem faced by agent $i$, a representative agent. Given the contract parameters, agent $i$ chooses effort $e_i$ to maximize expected utility.

$$\begin{aligned} \max_{e_i} \quad u_i &\equiv \int U\Big(\alpha + \beta x_i + \gamma Q - C(e_i)\Big) g(\epsilon, \phi) \mathrm{d}\epsilon \mathrm{d}\phi \\ &\equiv \int U\Big(\alpha + \beta\left[e_i + \epsilon_i + \phi_i\right] + \gamma \sum_{j=1}^{n} (e_j + \epsilon_j) - C(e_i)\Big) g(\epsilon, \phi) \mathrm{d}\epsilon \mathrm{d}\phi \end{aligned} \tag{5}$$

where $g(\epsilon, \phi)$ is the product of $2n$ marginal density functions. An interior solution to this problem satisfies

$$[\beta + \gamma - C'(e_i)] \int U'(\cdot) f(\epsilon) \mathrm{d}\epsilon = 0 \tag{6}$$

for all $i$. Consequently, $\beta + \gamma = C'(e_i)$ implicitly defines $e = e(\beta + \gamma)$, each worker's choice of effort given the contract parameters. Since the cost of effort is a strictly convex function with $C'(0) = 0$, $e(\beta + \gamma) > 0$ is the unique maximum. Therefore, the first-order approach is a valid method for solving for the optimal contract.

*Optimal Contract*

The employer chooses $\{\alpha, \beta, \gamma, e\}$ to maximize expected profit,

$$\pi = \sum_{i=1}^{n} \Big( p e_i - \alpha - \beta e_i - \gamma \sum_{j=1}^{n} e_j \Big) \tag{7}$$

[2]Competition drives the expected profit of firms in the optimal contract to zero. Thus, in the equilibrium setting, $\overline{u}$ would be determined to generate $\pi = 0$. This is used below to express the optimal base pay $\alpha^*$.

subject to (a) the participation constraints, $\overline{u} = u_i$ for all $i$, and (b) the $n$ incentive compatibility conditions, equations (6). With the $n$ incentive compatibility constraints substituted into the objective and the participation constraints, the streamlined problem becomes

$$\max_{\{\alpha,\beta,\gamma\}} \quad \pi = \{[p-\beta-n\gamma]e(\beta+\gamma)-\alpha\}n \tag{8a}$$

subject to

$$\overline{u} = \int U\Big(\alpha+[\beta+n\gamma]e(\beta+\gamma)+\beta\,[\epsilon_i+\phi_i]+\gamma\sum_{j=1}^{n}\epsilon_j - C[e(\beta+\gamma)]\Big)g(\boldsymbol{\epsilon},\boldsymbol{\phi})\mathrm{d}\boldsymbol{\epsilon}\mathrm{d}\boldsymbol{\phi} \tag{8b}$$

for all $i$.

A useful method for characterizing the solution under risk aversion is to assume (a) preferences exhibit constant absolute risk aversion, so $U(w-C(e)) \equiv -\exp(-r\,[w-C(e)])$, where $r \equiv -U''(\,\cdot\,)/U'(\,\cdot\,) \geq 0$ is the coefficient of absolute risk aversion; and (b) the i.i.d. random variables $\epsilon_i$ and $\phi_i$ are distributed normally with variances $\sigma^2$ and $\sigma_\phi^2$. With these assumptions, the participation constraint simplifies to

$$\begin{aligned}\overline{u} &= \int -\exp\Big\{-r\Big(\alpha+(\beta+n\gamma)e+\beta\,[\epsilon_i+\phi_i]+\gamma\sum_{j=1}^{n}\epsilon_j - C(e)\Big)\Big\}g(\boldsymbol{\epsilon},\boldsymbol{\phi})\mathrm{d}\boldsymbol{\epsilon}\mathrm{d}\boldsymbol{\phi}, \\ &\equiv -\exp\Big\{-r\overline{y}\ + r^2\sigma_y^2/2\Big\}\end{aligned} \tag{9}$$

where $\overline{y} \equiv \alpha+(\beta+n\gamma)e-C(e)$ is expected net income, and $\sigma_y^2 \equiv \Big(\beta^2+n\gamma^2+2\beta\gamma\Big)\sigma^2+\beta^2\sigma_\phi^2$ is the variance of compensation.

The first-order conditions imply that the optimal contract satisfies the following two conditions:

$$C'(e) = p - \Big[\beta\,(\sigma^2+\sigma_\phi^2)+\gamma\sigma^2\Big]rC'' \tag{10a}$$

$$C'(e) = p - (\beta+n\gamma)rC''\sigma^2 \tag{10b}$$

with $C''$ treated as a positive constant. Consequently, price exceeds the marginal cost of effort in the optimal contract if workers are risk averse.

The solution with risk neutral agents—$U'$ constant—is immediate. With $r = 0$, equations $(10a)$ and $(10b)$ both reduce to $p = C'(e)$; thus the first-best level of effort obtains: $e^* = e_0$. By the incentive compatibility constraint, $\beta + \gamma = C'(e)$; thus $\beta^* + \gamma^* = p$. The contract parameters are not unique: any combination of the two performance parameters that sums to $p$ is optimal.

The solution would be unique if individual performance were completely unobserved. In this case $\beta = 0$ is imposed, and the optimal team performance parameter under risk neutrality $\gamma^*$ equals the product price $p$. The first-best obtains by paying each worker the product price for each unit of *total* output and selling jobs at price $-\alpha^* = (n-1)pe_0$ per job. This is the simple team performance contract described in the introduction.

With $\pi = 0$, equations $(10a)$, $(10b)$, $(6)$, and $(8a)$ are four equations in the four unknowns $\{\alpha, \beta, \gamma, e\}$ to be solved simultaneously for the optimal contract parameters $\{\alpha^*, \beta^*, \gamma^*, e^*\}$. The solution is

$$\beta^* = \frac{p}{1 + rC''\sigma^2 + \Big(1 + rC''\sigma^2 n\Big)J} \geq 0 \tag{11a}$$

$$\gamma^* = \frac{Jp}{1 + rC''\sigma^2 + \Big(1 + rC''\sigma^2 n\Big)J} \equiv J\beta^* \geq 0 \tag{11b}$$

$$C'(e^*) = \frac{p}{1 + rC''\sigma^2\left\{\frac{1+nJ}{1+J}\right\}} \geq 0 \tag{11c}$$

$$\alpha^* = (p - \beta^* - n\gamma^*)e^* \gtrless 0. \tag{11d}$$

where $J \equiv \sigma_\phi^2 \big/ (n-1)\sigma^2$ measures the relative importance of error in measuring personal performance.

With individual performance measured with error, the optimal contract trades off the extra risk from noisy personal performance with the extra risk from team incentives. From equation (11*b*), the ratio of the performance parameters depends on only the ratio of the variances and the size of the firm.[3]

If personal performance were measured precisely (i.e., as $\sigma_\phi^2 \to 0$), then the solution would simplify to the standard individualistic solution. However, with errors in measuring personal performance, the optimal contract accepts additional risk from team performance to provide stronger incentives. Generally, the noisier is the signal of personal performance, the weaker are total performance incentives, the stronger are team incentives, and the lower is effort. (These and other comparative static results are reported in the Appendix.) Indeed, if personal performance evaluation has no content (i.e., $\sigma_\phi^2 \to \infty$), personal performance incentives vanish, and team incentives strengthen to $\gamma^* = p \Big/ \left(1 + rC''\sigma^2 n\right)$; so each worker behaves as if he were $n$ times as risk averse.

Although total incentives and effort respond to production risk in familiar ways, personal performance incentives can increase with production risk. The sum $\beta^* + \gamma^*$ and $e^*$ are decreasing functions of the variance of the production shocks $\sigma^2$, but the optimal contract responds to increased production risk by shifting weight from team incentives $\gamma^*$ to personal incentives $\beta^*$. If personal performance evaluation is sufficiently noisy, personal performance incentives would be an increasing function of the variance of the production shock.

Since the risk from team incentives increases with firm size $n$, effort and team incentives are decreasing functions of $n$; but personal performance incentives increase in $n$. Indeed, if $n$ is large (i.e., as $n \to \infty$), the optimal contract simplifies to the standard performance contract with errors in the measurement of personal performance: $\beta^* =$

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[3]In some applications, the performance of the individual is completely unobservable, but performance of the individual's department is observable with error. Let $Q_m \equiv \sum_{j=1}^{m} q_j + \phi_m$ be the error-ridden measure of output of a department with $m$ workers. In the optimal contract, the ratio of the two performance parameters is $\gamma^*/\beta^* = \sigma_\phi^2/(n-m)\sigma^2$, which reduces to $J$ for the special case of $m = 1$, a one-member department.

$p \Big/ 1 + rC''\left(\sigma^2 + \sigma_\phi^2\right)$. So the advantage of team incentives goes to zero in very large firms.

*Discussion*

Casual observation suggests that the fortunes of workers are generally related to the fortunes of the firm that employs them. An individual's compensation depends not only on his own performance but also on the performance of the firm. Standard models of competitive wage determination imply that the wage should be independent of the performance of the firm. If the firm bears a negative productivity shock, it reduces employment but continues to pay each employed worker the market wage. Team incentives produce the positive relationship between firm performance and individual compensation.[4] In particular, the model generates predictions of the conditions under which firm performance and individual compensation are most strongly linked. Risk aversion, production risk, and inelastic effort supply weaken team incentives for familiar reasons. In addition, conditional on an assessment of individual performance, the link between a worker's compensation and his firm's performance is stronger the smaller is the firm and the noisier is the signal of personal performance.

The principal advantage of team incentives is that it economizes on the cost of measuring personal performance. Even if personal performance is measured with substantial noise, strong incentives can be provided through team performance pay. In particular, with risk neutral workers, the first-best level of effort obtains.

A second advantage is that team incentives enhance cooperation among workers. With relative performance evaluation, each worker has the incentive to sabotage his co-workers efforts. This promotes pay compression to reduce unproductive competition among co-work-

[4]Models of risk sharing and matching also generate this result. In the risk sharing model, even a risk averse worker would bear some of the risk facing a risk averse principal. In a matching model with flexible wages, firm-level fluctuations affect the worker's productivity and wage. An infra-marginal worker accepts a wage cut rather than separating to a lower quality match. See, e.g., McLaughlin (1994a).

That team incentives generate a direct link between individual compensation and firm performance contrasts with relative performance evaluation. Payment by relative performance generates a negative relationship between individual compensation and firm performance. See Holmstrom (1982), Carmichael (1983), and Gibbons and Murphy (1990).

ers (Lazear 1989). Team rewards provide the opposite incentives. A worker who helps his co-workers increases his pay. To the extent cooperation is productive—that is, with workers as complements in production[5]—this indicates another advantage of team incentives.

One disadvantage is immediate. Conditioning compensation on total output introduces more risk as each agent must bear the risk of all the workers' outputs. This is clearest where personal performance is unobservable. Each worker behaves as if he were $n$ times as risk averse. Thus the model does not predict a strong link between firm performance and individual compensation in large firms.

## III. Trouble with Teams

Incentives derived from firm performance are likely to be weak if (a) workers are risk averse and production is risky, (b) effort supply is inelastic, (c) the firm is large, and (d) there are good proxies for each worker's performance. In addition, several problems with team incentives also weaken the link between individual compensation and firm performance. These problems become apparent as I enrich the environment to allow for more complex forms of malfeasance, such as sabotage, collusion, and adverse selection.

### *Sabotage*

An implicit assumption governing the contracting environment is that workers can preclude the principal from sabotaging production. This assumption is innocuous in the context of most contracting models. The assumption is not innocuous with team incentives. Indeed, in the simplest team performance contract, the principal has the incentive to behave as an agent in sabotaging production (McAfee and McMillan 1991, 563–64). In this subsection, I characterize the conditions conducive to sabotage, as well as the optimal sabotage-compatible team performance contract. If team incentives are strong, team performance pay induces the employer to sabotage production.

[5] I model production under the assumption of additivity, but complementarities among workers would clearly produce stronger team incentives in the optimal contract.

Define the quasi-indirect profit function $\pi(\delta)$, where $\delta > 0$ is the amount of output destroyed by sabotage.

$$\pi(\delta) \equiv (ne^* - \delta)[p - \beta^* - n\gamma^*] - n\alpha^* - B(\delta), \tag{12}$$

where the cost of sabotage $B(\delta)$ is an increasing convex function of the amount of sabotage with $B(0)=0$ and $B'(0)=0$. This construction implies that the Pareto optimal level of sabotage is zero. By the envelope theorem, $\pi'(0) = \beta^* + n\gamma^* - p \equiv -\alpha^*/e^* \gtrless 0$. Consequently, the employer has an incentive to sabotage production if workers buy their jobs: $\alpha^* < 0$. Employer sabotage is more likely to be a problem where team incentives are strong, such as where personal performance evaluation is noisy and risk aversion is weak. Although $\gamma^*$ is smaller in large firms, $n\gamma^*$ is an increasing function of $n$; this points to employer sabotage as a bigger problem in large firms.

Rational workers respond to potential sabotage in designing an optimal contract. For tractability, consider the optimal contracting problem when individual performance is unobservable, so $\beta = 0$. It is straightforward to establish that incentive compatible sabotage must satisfy $p + B'(\delta) - n\gamma \geq 0$ for $\delta \geq 0$. (This implies that with $\beta = 0$ the employer would choose to sabotage production if team incentives were stronger than revenue sharing: $\gamma > p/n$). With $\hat{e}$ denoting the solution to each of the $n$ individual incentive compatibility conditions, the optimal contracting problem is to choose the other contracting parameters $(\alpha, \gamma, \delta)$ to maximize expected profit

$$\pi = (n\hat{e} - \delta)[p - n\gamma] - n\alpha - B(\delta) \tag{13a}$$

subject to

$$p + B'(\delta) - n\gamma \geq 0 \tag{13b}$$

$$\overline{u} = -\exp\Big\{-r(\alpha + \gamma(n\hat{e} - \delta) - C(\hat{e}) - B(\delta)) + \tfrac{1}{2}r^2\gamma^2\sigma^2 n\Big\} \tag{13c}$$

and the non-negativity constraint $\delta \geq 0$. (Constant absolute risk aversion has been used to

express the participation constraint.)

The Kuhn-Tucker conditions imply that

$$C'(e) = p - \psi C'' - \gamma r C'' \sigma^2 n \tag{14a}$$

$$[\psi B'' - p - B'(\delta)]\delta = 0 \tag{14b}$$

$$[p + B'(\delta) - n\gamma]\psi = 0 \tag{14c}$$

$$C'(e) = \gamma \tag{14d}$$

where $\psi$ is the multiplier associated with the incentive compatible sabotage constraint, (13$b$). The solution is characterized in three parts. The first corresponds to the interior solution, the second to the corner solution ($\delta = 0$) with the sabotage condition binding, and the third to the corner solution without an incentive for sabotage.

If $\gamma^{**} > p/n$, employer sabotage $\delta$ is positive, and the solution is interior.

$$C'(e^{**}) = \gamma^{**} = \frac{p}{1 + rC''\sigma^2 n + nC''/B''} \geq 0 \tag{15a}$$

$$p + B'(\delta^{**}) = n\gamma^{**} \geq 0 \tag{15b}$$

So if sabotage exists in equilibrium, team incentives and effort fall: $\gamma^{**} < \gamma^*$, and $e^{**} < e^*$.

Alternatively, the optimal contract must satisfy the corner solution of $\delta = 0$. If the incentive compatible sabotage conditions binds at $\delta = 0$, $\psi > 0$ and optimal contract shares revenue: $C'(e^{**}) = \gamma^{**} = p/n$, and $\alpha^{**} = 0$. Paying each worker an $n$th of the firm's revenue does not induce sabotage from the employer, but any team performance parameter exceeding $p/n$ would generate sabotage. Again team incentives and effort fall due to potential sabotage.

If $\gamma^* \leq p/n$, the employer has no incentive to sabotage production. The incentive

compatible sabotage condition would not bind (i.e., $\psi = 0$), and optimal team incentives would not affected by the potential for employer sabotage. That is, $\gamma^{**} = \gamma^*$.

Figure 1 illustrates these results. The figure displays two functions of $rC''\sigma^2$; these are $\gamma^* = p/\left(1+rC''\sigma^2 n\right)$, which is the solution in the absence of a sabotage problem, and $\gamma^{**}$ from equation (15$a$). The optimal contract sets $\gamma$ equal to $\gamma^*$ for values of $rC''\sigma^2$ so high that sabotage is not an issue. For intermediate values of $rC''\sigma^2$, the team performance parameter is set to $p/n$. If $rC''\sigma^2$ is small, so risk is not much of a problem, the optimal contract accepts some sabotage in order to generate stronger incentives; the team performance parameter follows $\gamma^{**}$ over this interval.

Overall, sabotage compresses the relationship between individual pay and firm performance, which could account for why team incentives are not strikingly strong (e.g., $\gamma = p$). However, there is no role for sabotage in weakening incentives unless workers buy their jobs.

*Collusion*

The team performance contract characterized in section II is suboptimal if workers can collude to *increase* effort. In this subsection, I show that team incentives promote collusion or peer pressure among workers to increase effort. The intuition is simple. If *all* workers increase effort by a small amount, *each* worker's pay rises by $n$ times the marginal product of effort.[6] Given this incentive, optimal team incentives must allow for incentive compatible collusion. In enriching the environment to allow for collusion, I demonstrate that collusion-compatible team incentives attenuate strong team incentives and accentuate weak team incentives. Either way, collusion does not vanish in the optimal contract.

Team performance incentives invite workers to collude to increase effort. Let $\eta \gtrless 0$ denote collusive effort, the collusive agreement's deviation from the individual incentive compatible level of effort $\hat{e}$; so a worker's total effort is $\hat{e} + \eta$. The personal cost of policing

[6]Tirole (1986), Holmstrom and Milgrom (1990), and Varian (1990) also explore collusion in teams. For instance, Tirole models the incentives for a supervisor to report information about worker's performance to the principal. Kandel and Lazear's (1992) work on peer pressure is closest to my approach; however, their analysis is limited to pure partnerships (i.e., $\gamma = p/n$).

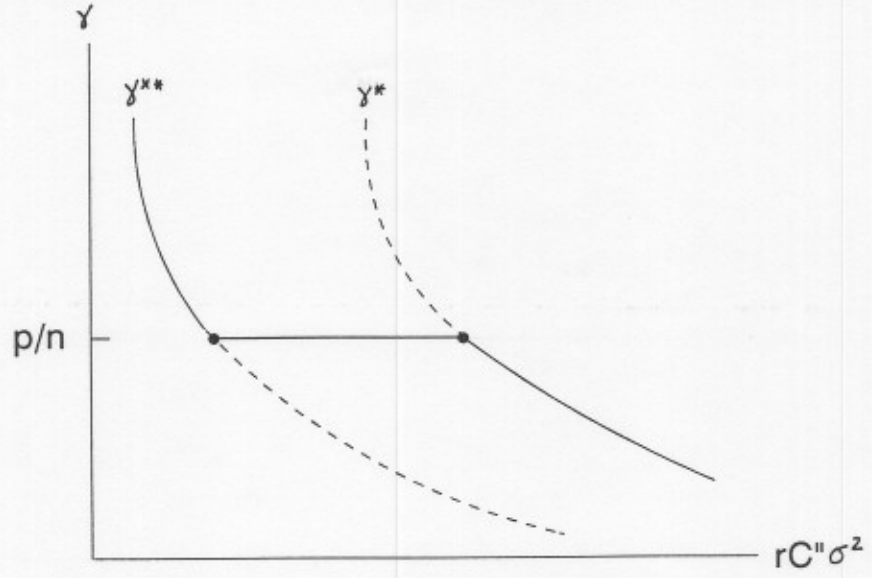


Fig. 1: Sabotage-Compatible Team Incentives

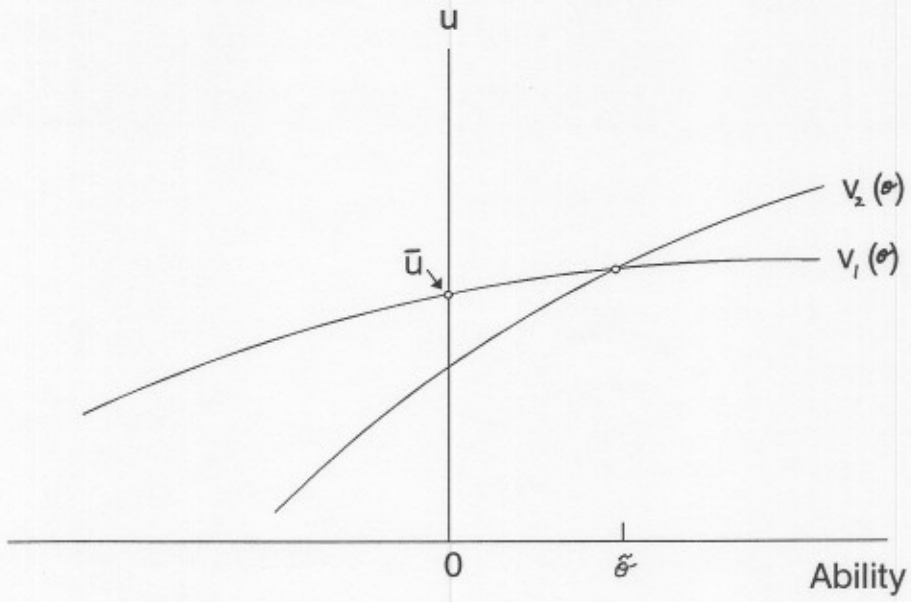


Fig. 2: Adverse-Selection-Compatible Team Incentives

collusion, $B(\eta)$, is assumed to be quadratic with $B(0) = 0$ and $B'(0) = 0$. This captures the important feature that any deviation away from individually incentive compatible effort must be costly to enforce; that is, peer pressure is costly. (The construction also implies that the Pareto optimal level of collusion is zero.) Expected utility is a function of collusive effort $\eta$, as well as the contract parameters $\{\alpha, \beta, \gamma\}$.

$$v(\eta) \equiv \int U\Big(\alpha + (\beta + n\gamma)(\hat{e} + \eta) + \beta[\epsilon_i + \phi_i] + \gamma \sum_{j=1}^{n} \epsilon_j - C(\hat{e} + \eta) - B(\eta)\Big) g(\epsilon, \phi) \mathrm{d}\epsilon \mathrm{d}\phi \quad (16)$$

Since $v'(0) = (n-1)\gamma\lambda \geq 0$, where $\lambda$ is the marginal utility of income, there exists peer pressure to increase effort unless personal performance is measured precisely (i.e., $\sigma_\phi^2 = 0$).

To determine the incentive compatible amount of collusive effort, set $v'(\eta)$ to zero.

$$\beta + n\gamma = C'(\hat{e} + \eta) + B'(\eta) \quad (17)$$

This implicitly defines $\eta$ as function of the contract parameters and firm size $n$; in particular, collusive effort $\eta$ is an increasing function of team incentives $\gamma$. Together with $v'(0) \geq 0$, this implies that collusive effort is always positive if team incentives are positive.

The employer is not indifferent to collusion, but whether it increases or decreases profit depends on the strength of team incentives. With collusion, expected profit $\pi$ is

$$\pi = \{(p - \beta - n\gamma)(\hat{e} + \eta) - \alpha\} n \quad (18a)$$

So

$$\pi'(\eta) \equiv \{p - \beta - n\gamma\} n \gtrless 0 \quad \text{as} \quad \alpha \gtrless 0. \quad (18b)$$

So if workers do not buy their jobs, the employer benefits from the workers' collusion to increase effort. However, if workers buy their jobs—so team incentives are particularly strong—peer pressure is a problem for the employer.

The firm rationally responds to potential collusion in designing an optimal contract. For tractability, consider the optimal contracting problem with personal performance

completely unobservable, so $\beta = 0$. The optimal contracting problem is to choose contracting parameters ($\alpha$, $\gamma$, $\eta$) to maximize expected profit (equation (18$a$)) subject to incentive compatible collusion (equation (17)) and the participation constraint.

$$\overline{u} = -\exp\Big\{-r(\alpha + n\gamma(\hat{e}+\eta) - C(\hat{e}+\eta) - B(\eta)) + \tfrac{1}{2}r^2\gamma^2\sigma^2 n\Big\} \tag{19}$$

With $\psi$ denoting the multiplier associated with collusion, the optimal contract must satisfy four conditions.

$$p = C'(\hat{e}+\eta) + (n-1)\psi C'' + \gamma r C''\sigma^2 n \tag{20a}$$

$$\psi = \frac{n\gamma - p}{C'' + B''} \gtrless 0 \tag{20b}$$

and the two incentive compatibility conditions, equations (17) and (14$d$).

The character of the solution depends on whether team incentives are stronger or weaker than revenue sharing.[7] Suppose $\gamma^* > p/n$, so team incentives are stronger than in a partnership. Then $\psi > 0$, which reinforces risk aversion in reducing total effort. (The last two terms in equation (20$a$) would be positive.) Since individual effort $\hat{e}$ and collusive effort $\eta$ are both increasing functions of the team performance parameter $\gamma$, team incentives must fall in response. Weakening team incentives reduces total effort, even though peer pressure raises effort above $\hat{e}$. Peer pressure, which is not free, would be excessive without reducing team incentives. This is most striking with risk neutrality (so $\gamma^* = p$) in large firms; $\psi$ would be quite big, driving optimal team incentives down toward $p/n$.

But with $\gamma^* < p/n$, the employer promotes peer pressure by strengthening team incentives. The multiplier associated with collusion is negative, so (from equation (20$a$)) collusion attenuates the effect of risk aversion, driving $\gamma$ up toward $p/n$.[8] Both individual and collusive efforts rise in response.

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[7] Revenue sharing in a partnership would promote peer pressure, but the optimal team incentives would not deviate from $\gamma^* = p/n$ in response to the peer pressure. ($\psi$ would equal zero.) This supports Kandel and Lazear's (1992) analysis of peer pressure in partnerships. Their *assumption* of partnership is robust to peer pressure.

Consequently, collusion alone can account for why team incentives are not nearly as strong as under the simplest team performance contract (i.e., $\gamma = p$). But collusion cannot explain why team incentives are weak unless workers buy their jobs. Indeed, if workers do not buy their jobs, the contract increases team incentives to promote peer pressure.

*Adverse Selection*

The final enrichment introduces heterogeneity among workers. The modification is simple if the heterogeneity is observable. For instance, if the employer observes the skills of the worker, the intercept of the team performance contract would be indexed to these skills. More productive workers would be paid more, but marginal incentives would not be affected. If differences in productive ability are not observable, the contract's intercept could not be indexed to skills: the best workers would subsidize the worst workers, because each worker is paid in part on the basis of firm performance. If the team performance contract must compete with standard (i.e., individualistic) contracts, more productive workers would sort into the standard contracts. To avoid adverse selection, the team performance contract increases the return on personal performance (relative to the solution presented in section II) and decreases the return on firm performance.

To establish these results, I model productive ability $\theta \in \mathbb{R}$ as a mean-zero additive component of production: $q_i = e_i + \theta_i + \epsilon_i$. (The analysis of section II corresponds to the special case of $\theta_i = 0$ for all $i$.) Under the team performance contract, the indirect expected utility of a worker of productive ability $\theta_i$ is

$$v_1(\theta_i) \equiv \int U\Big(\alpha^* + \beta^* \left[e^* + \theta_i + \epsilon_i + \phi_i\right] + \gamma^* \sum_{j=1}^{n} (e^* + \epsilon_j) - C(e^*)\Big) g(\epsilon, \phi) \mathrm{d}\epsilon \mathrm{d}\phi \qquad (21a)$$

with $v_1(0) = \overline{u}$. If this worker were compensated via the standard (i.e., individualistic)

[8] Rotemberg (1994) analyzes incentives in teams with endogenous altruism. He demonstrates that altruism toward co-workers arises endogenously with team incentives. In the context of my model, altruism would reduce the cost of policing the collusive agreement, which increases team incentives in effort if $\gamma^* < p/n$. Rotemberg does not consider the case with $\gamma > p/n$.

performance contract, his expected utility would be

$$v_2(\theta_i) \equiv \int U\Big(\alpha_2 + \beta_2\,[e_2 + \theta_i + \epsilon_i + \phi_i] - C(e_2)\Big) g(\epsilon_i, \phi_i) \mathrm{d}\epsilon_i \mathrm{d}\phi_i. \tag{21b}$$

Since the team performance contract dominates in the absence of adverse selection, the worker of average ability prefers team incentives: $v_2(0) < \overline{u}$.

The two indirect utility functions, which are illustrated in Figure 2, are increasing concave functions of $\theta$.

$$v_1'(\theta) \equiv \lambda_1 \beta^* > 0 \quad \text{and} \quad v_1''(\theta) \equiv \beta^*\, \partial\lambda_1/\partial\theta < 0 \tag{22a}$$

$$v_2'(\theta) \equiv \lambda_2 \beta_2 > 0 \quad \text{and} \quad v_2''(\theta) \equiv \beta_2\, \partial\lambda_2/\partial\theta < 0 \tag{22b}$$

where $\lambda_1$ and $\lambda_2$ are the marginal utilities of income under the two contracts. Furthermore, there is some unique positive value of $\theta$, denoted $\tilde{\theta}$, that equates the two functions. That is, there exists some above-average worker who is indifferent between the two contracts. In addition, the standard performance contract yields a higher expected utility to more productive workers: $v_2(\theta) > v_1(\theta)$ for all $\theta > \tilde{\theta}$.[9] Consequently, more productive workers (i.e., $\theta > \tilde{\theta}$) select into jobs that pay on the basis of individual performance, and less productive workers (i.e., $\theta < \tilde{\theta}$) select the team performance contract.[10] The familiar lemons result applies, so the team performance contract would vanish from the market.

Workers and their employers rationally respond to the problem of adverse selection.

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[9]To prove these assertions with constant absolute risk aversion is straightforward. Here I sketch four components of a proof. (A proof of each component is available on request.) First, $v_1(0) > v_2(0)$. Second, $v_1$ is flatter than $v_2$ where $v_1(\theta) > v_2(\theta)$. Therefore, $v_1(\theta) > v_2(\theta)$ for $\theta \leq 0$. Third, at any intersection of the two functions, $v_1$ must be flatter than $v_2$; so these continuous functions cross at most once. Fourth, $v_2$ exceeds $v_1$ in the limit as $\theta \to \infty$. Therefore, $\tilde{\theta}$ uniquely solves $v_1(\theta) = v_2(\theta)$, and $v_2(\theta) > v_1(\theta)$ for all $\theta > \tilde{\theta}$.

[10]McAfee and McMillan (1991) also analyze adverse selection in a model with team incentives. However, they find that satisfying the participation constraint is most difficult for *low-ability* workers. Their model differs from mine in many ways, but most importantly their low-ability workers have higher costs of effort. If all workers were treated the same, adverse selection would require raising the level of pay to attract low-ability workers. Low-ability workers would subsidize high-ability workers, who would be infra-marginal. This result is insightful; but with equal pay (based on collective performance) for unequal performances, keeping the best and the brightest must be the salient problem.

Leaving each worker indifferent between a team performance contract and the standard performance contract is sufficient to deter adverse selection. That is, an indirect utility function from a team performance contract that is coincident with $v_2(\theta)$ deters adverse selection. Since expected utility is equalized for each value of $\theta$, so is the marginal utility of income; therefore, the personal performance parameter in the team performance contract $\beta^{**}$ must equal $\beta_2$, the personal performance parameter in the standard contract.

Team incentives survive. Although constrained to offer a contract with $\beta^{**} = \beta_2$, the expected profit maximizing contract includes positive team incentives.[11] The incentive compatibility constraint (equation (6)) and the first-order condition governing the choice of $\gamma$ (equation (10*b*)) imply that team incentives are a decreasing function of the personal performance parameter $\beta$.

$$\gamma = \frac{p - \left(1 + rC''\sigma^2\right)\beta}{1 + rC''\sigma^2 n} \tag{23}$$

Given deterrence of adverse selection, team performance incentives are found by substituting $\beta^{**} = \beta_2 = p \Big/ \left(1 + rC''\left(\sigma^2 + \sigma_\phi^2\right)\right)$ into equation (23). If workers are risk averse and personal performance is measured with error, the optimal team performance parameter that deters adverse selection is positive.

$$\gamma^{**} = \frac{prC''\sigma_\phi^2}{\left(1 + rC''\sigma^2 n\right)\left[1 + rC''\left(\sigma^2 + \sigma_\phi^2\right)\right]} > 0 \tag{24}$$

which is less than $\gamma^*$.

Rational employers and workers respond to potential adverse selection by increasing personal performance incentives and decreasing team performance incentives. Because $\beta^{**}$ rises faster than $\gamma^{**}$ falls, effort $e^{**}$ rises in response to the threat of adverse selection.

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[11] Competition among firms would drive up expected utility in the team performance contract. However, higher expected utility and deterrence of adverse selection are not compatible with *linear* performance contracts. To equalize slopes of the indirect utility functions, marginal personal performance incentives must be an increasing function of performance. Details are available on request.

Adverse selection is deterred; and team incentives survive, although with a weaker link between individual pay and firm performance.

*Comparison*

Risk aversion, borrowing constraints, sabotage, collusion, and adverse selection all can attenuate the powerful team incentives described in the introduction. In particular, the analyses of sabotage, collusion, and adverse selection demonstrate that the simplest team performance contract is quite sensitive to these richer forms of malfeasance. But like borrowing constraints, sabotage and collusion are not a problem unless workers buy their jobs. Since workers do not buy jobs, the analysis points to risk aversion and adverse selection. The relative importance of each can be determined in an application to executive compensation.

## IV. Application

Team incentives form the foundation of the literature on executive compensation, which estimates the effect of firm performance on the compensation of the CEO. Jensen and Murphy (1990, 226) state explicitly that although the return to shareholders depends on the actions of other executives and employees, "it is appropriate, however, to pay CEOs on the basis of shareholder wealth since that is the objective of the shareholders." Their conclusion builds from the premise that shareholders do not have good indicators of the CEO's personal performance.

Jensen and Murphy estimate that the simple team performance contract for CEOs has a team performance parameter of .0000329 per dollar of output, which is quite small. They conclude that their "results are inconsistent with the implications of formal agency models of optimal contracting." Intuitively, the estimated team performance incentives are just too small to generate meaningful incentives. Team performance incentives might be weak, but the model of team incentives does not predict a strong link between individual compensation

and firm performance in large firms, such as those in the *Forbes* sample studied by Jensen and Murphy. In addition, the theory is consistent with Jensen and Murphy's (1990, Table 11) evidence that team incentives are weaker in larger firms.

If team incentives are supplemented with personal performance incentives, overall incentives for CEO performance might be quite strong. The within-CEO variance of compensation is high: CEO pay jumps around substantially, much more than would be implied by $\gamma = .0000329$ alone (McLaughlin 1994b). Thus the compensation data call for a team incentives model that includes personal performance incentives.[12] This also enables the model to account for stronger team incentives at the top of organizations, where personal performance is difficult to measure.

It might be valuable, therefore, to calibrate the theoretical model to predict the magnitude of the CEO's team performance parameter. Does the team incentives model fit the estimates of $\gamma$? Is the same calibration consistent with the level and variance of executive compensation?[13]

*Method*

My tasks are (a) to compute the theoretically implied values of the personal performance parameter $\beta$, the team performance parameter $\gamma$, the level of pay $Ew$, and the variance of pay $\sigma_w^2$, and (b) to contrast the theoretical values with corresponding estimates from the literature. From Jensen and Murphy (1990, 244), we have that the median total

[12]For CEOs, as well as middle managers, librarians, and research assistants, evaluating *personal* performance is hampered by lack of data. Nevertheless, one's supervisor almost always has a good idea of how well one performs. The supervisor knows whether the worker is energetic, creative, organized, reliable, open minded, knowledgeable, and willing to learn; and whether the employee thinks clearly, has sharp ideas, works well with others, and gets the job done. The board of directors is likely to have a good idea whether the CEO is forming and retaining a good team of top executives, working well with his top executives, developing a creative corporate strategy, and responding promptly to new opportunities and initiatives. These characterizations generate $x_i$, the measure of personal performance. Consequently, it would be unreasonable to assume that the only information is the performance of the firm.

[13]Haubrich (1994) also applies the linear incentives model to Jensen and Murphy's estimate of performance pay. However, Haubrich uses neither the level nor variance of executive compensation to evaluate the calibration. Also, his specification assumes $\beta = 0$.

compensation of CEO's in their *Forbes* sample is \$490,000 (1986\$), as well as that $\gamma = .0000329$. Adjusting for observables and unobserved fixed effects, I use Jensen and Murphy's sample to compute the standard deviation of CEO pay: $\sigma_w = \$83{,}300$. The model is calibrated from equations (11*a*)–(11*d*), with the level of pay based on zero expected profit (and the product price normalized to one) . The implied variance of pay is

$$\sigma_w^2 \equiv \beta^2(\sigma^2 + \sigma_\phi^2) + \gamma^2\sigma_F^2 + 2\beta\gamma\sigma^2 \tag{25}$$

The quality of the calibration hinges on the quality of the parameters. First, a key parameter is the variance of firm value, $\sigma_F^2 \equiv n\sigma^2$. Jensen and Murphy (1990, 230) report that the median value of $\sigma_F$ in their sample is \$200 million. Second, I vary the coefficient of absolute risk aversion $r$ from $0.1 \times 10^{-5}$ to $10 \times 10^{-5}$, which implies the coefficient of *relative* risk aversion ranges from .49 to 49. Third, to gauge the quality of the CEO's personal performance measure, I vary a reliability statistic, $\lambda \equiv \sigma^2/(\sigma^2 + \sigma_\phi^2)$, from zero to one. This corresponds to varying $J$ from infinity down to zero—from all team incentives to no team incentives. Since the literature assumes the only information is firm performance, I focus on $\lambda = .15$ to access the impact of a little information about personal performance. Fourth, for the slope of effort supply, $c_1 \equiv C''$, Haubrich (1994, 274) chooses $c_1 = 2 \times 10^{-9}$. This would imply that a .01-increase in $\gamma$ would increase CEO performance by $.01/c_1 = \$5$ million, or ten times their average performance. Where $c_1$ is a free parameter, I vary it between $1 \times 10^{-8}$ and $10 \times 10^{-8}$. With $c_1 = 4 \times 10^{-8}$, increasing incentives by .01 would increase expected performance by \$250,000, which is still sizable. Since team incentives are a decreasing function of the slope of effort supply, still higher values of $c_1$ would render Jensen and Murphy's mystery of weak incentives less mysterious.

*Results*

If the cost of effort were quadratic, effort supply would be a ray from the origin with slope $c_1$. In this case, $c_1$ is not free; it must solve the incentive compatibility condition to

yield $Ew$ of \$490,000. If incentives were weak, effort supply would have to be quite flat to justify the high level of pay. This is displayed in Table 1, which lists solutions for $c_1, \gamma,$ and $\sigma_w$ for various coefficients of absolute risk aversion. Confirming Jensen and Murphy's conjecture, the calibrated team incentives parameter is too big. For instance, at $r = 1 \times 10^{-5}$, $\gamma$ is 33 times larger than Jensen and Murphy's estimate. Even with $r$ as large as $10 \times 10^{-5}$, the calibrated $\gamma$ is 10 times larger than its empirical counterpart.

The estimates in Table 1 reveal how flat effort supply must be to account for the level of executive compensation. With $r = 1 \times 10^{-5}$, a .01-increase in $\gamma$ would increase the CEO's expected output by $.01/c_1$, or \$4.4 million. Alternatively, effort supply's intercept $c_0$ can be used to pin down the level of pay, which frees its slope $c_1$ to match incentives. Perhaps team incentives are weak because effort supply is fairly inelastic.

The first panel of Table 2 (with $\lambda = 0.0$) displays the results for various values of $c_1$, as well as various degrees of risk aversion. (Since $\lambda = 0$, $J = \infty$, and $\beta = 0$ in this panel.) With $c_1 = 4 \times 10^{-8}$ and $r = 1 \times 10^{-5}$, $\gamma = .00006$, which is still twice as large as Jensen and Murphy's estimate. Team incentives $\gamma$ can be driven smaller by steepening effort supply (i.e., increasing $c_1$) or strengthening risk aversion (i.e., increasing $r$). But the primary problem with the results in the first panel of Table 2 is that low $\gamma$'s imply low standard deviations of pay $\sigma_w$.

The rejection is not surprising since personal performance evaluation is excluded. To remedy this, I move beyond Haubrich's recent calibration by distinguishing personal from team incentives. The remaining three panels of Table 2 display solutions for $\beta$, $\gamma$, and $\sigma_w$, given some content to personal performance evaluation; that is, $\lambda > 0$. Consistent with the theoretical derivations, positive $\beta$ attenuates $\gamma$. Indeed, a little information about personal performance is sufficient to align the calibrated and estimated $\gamma$'s, and strong total incentives are implied. For instance, with $\lambda = .15$: $\beta = .43$, $\gamma = .000030$. However, the model again fails to match the variance of pay: $\sigma_w$ soars to nearly \$800,000. This problem permeates the last three panels of Table 2.[14]

TABLE 1

**Calibration of Executive Compensation**[a]
Quadratic Cost of Effort

| Risk Aversion ($r \times 10^5$) | Slope of Effort Supply ($c_1 \times 10^9$) | Team Performance Parameter ($\gamma$) | Standard Deviation of Pay ($\sigma_w$) |
|---|---|---|---|
| 0.1 | 7.13 | .00349 | 698,776 |
| 0.5 | 3.19 | .00156 | 312,805 |
| 1.0 | 2.26 | .00111 | 221,237 |
| 2.0 | 1.60 | .00078 | 156,464 |
| 3.0 | 1.30 | .00064 | 127,761 |
| 4.0 | 1.13 | .00055 | 110,649 |
| 5.0 | 1.01 | .00049 | 98,970 |
| 6.0 | 0.92 | .00045 | 90,349 |
| 7.0 | 0.85 | .00042 | 83,649 |
| 8.0 | 0.80 | .00039 | 78,247 |
| 9.0 | 0.75 | .00037 | 73,773 |
| 10.0 | 0.71 | .00035 | 69,988 |

[a]Notes: Effort supply is constrained to be a ray from the origin. To account for median compensation, $e$ is set to \$490,000. The standard deviation of firm value is set to \$200 million.

TABLE 2

**Calibration of Executive Compensation**[a]

Linear-Quadratic Cost of Effort

| Reliability Statistic | Risk Aversion ($r \times 10^5$) | Slope of Effort Supply: $1.0 \times 10^{-8}$ $\beta$ | $\gamma$ | $\sigma_w$ | $4.0 \times 10^{-8}$ $\beta$ | $\gamma$ | $\sigma_w$ | $10.0 \times 10^{-8}$ $\beta$ | $\gamma$ | $\sigma_w$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.1 | .000 | .002494 | 498,753 | .000 | .000625 | 124,922 | .000 | .000250 | 49,988 |
| | 0.5 | .000 | .000500 | 99,950 | .000 | .000125 | 24,997 | .000 | .000050 | 10,000 |
| | 1.0 | .000 | .000250 | 49,988 | .000 | .000063 | 12,499 | .000 | .000025 | 5,000 |
| | 3.0 | .000 | .000083 | 16,665 | .000 | .000021 | 4,167 | .000 | .000008 | 1,667 |
| | 5.0 | .000 | .000050 | 10,000 | .000 | .000013 | 2,500 | .000 | .000005 | 1,000 |
| | 7.0 | .000 | .000036 | 7,143 | .000 | .000009 | 1,786 | .000 | .000004 | 714 |
| | 9.0 | .000 | .000028 | 5,555 | .000 | .000007 | 1,389 | .000 | .000003 | 556 |
| 0.15 | 0.1 | .968 | .000067 | 1,750,170 | .884 | .000061 | 1,598,483 | .754 | .000052 | 1,362,336 |
| | 0.5 | .860 | .000060 | 1,553,599 | .605 | .000042 | 1,093,174 | .380 | .000026 | 686,356 |
| | **1.0** | **.754** | **.000052** | **1,362,336** | **.434** | **.000030** | **783,555** | **.234** | **.000016** | **423,614** |
| | 3.0 | .505 | .000035 | 912,824 | .203 | .000014 | 367,363 | .093 | .000006 | 167,355 |
| | 5.0 | .380 | .000026 | 686,356 | .133 | .000009 | 239,925 | .058 | .000004 | 104,275 |
| | 7.0 | .304 | .000021 | 549,923 | .099 | .000007 | 178,131 | .042 | .000003 | 75,731 |
| | 9.0 | .254 | .000018 | 458,736 | .078 | .000005 | 141,649 | .033 | .000002 | 59,455 |
| 0.50 | 0.1 | .990 | .000012 | 980,339 | .962 | .000012 | 952,605 | .911 | .000011 | 901,591 |
| | 0.5 | .953 | .000012 | 943,705 | .836 | .000010 | 827,715 | .671 | .000008 | 664,395 |
| | 1.0 | .911 | .000011 | 901,591 | .718 | .000009 | 711,170 | .505 | .000006 | 499,974 |
| | 3.0 | .773 | .000009 | 765,029 | .460 | .000006 | 454,940 | .254 | .000003 | 251,257 |
| | 5.0 | .671 | .000008 | 664,395 | .338 | .000004 | 334,443 | .169 | .000002 | 167,788 |
| | 7.0 | .593 | .000007 | 587,158 | .267 | .000003 | 264,410 | .127 | .000002 | 125,948 |
| | 9.0 | .531 | .000007 | 526,009 | .221 | .000003 | 218,629 | .102 | .000001 | 100,810 |
| 1.00 | 0.1 | .995 | .000000 | 696,587 | .981 | .000000 | 686,544 | .953 | .000000 | 667,302 |
| | 0.5 | .976 | .000000 | 683,260 | .911 | .000000 | 637,523 | .803 | .000000 | 562,249 |
| | 1.0 | .953 | .000000 | 667,302 | .836 | .000000 | 585,284 | .671 | .000000 | 469,799 |
| | 3.0 | .872 | .000000 | 610,288 | .630 | .000000 | 440,806 | .405 | .000000 | 283,401 |
| | 5.0 | .803 | .000000 | 562,249 | .505 | .000000 | 353,535 | .290 | .000000 | 202,899 |
| | 7.0 | .745 | .000000 | 521,221 | .422 | .000000 | 295,110 | .226 | .000000 | 158,014 |
| | 9.0 | .694 | .000000 | 485,774 | .362 | .000000 | 253,256 | .185 | .000000 | 129,390 |

[a]Notes: The marginal cost of effort function is $C'(e) = c_0 + c_1 e$; the reliability statistic is $\lambda \equiv \sigma^2/(\sigma^2 + \sigma_\phi^2)$; and $\sigma_w$ is the standard deviation of compensation. To account for median compensation, $e$ is set to \$490,000. The standard deviation of firm value is set to \$200 million. The standard deviation of the production shock is set to \$700,000.

Within the context of the model, is there any combination of parameters that matches the variability of CEO pay, as well as the strength of team incentives? To answer this question, I (a) fix $\gamma$ at .0000329 and $\sigma_w$ at \$83,300 (and keep $\sigma_F$ at \$200 million) and (b) search numerically for values of $\lambda$ and $\sigma$ that solve both (11$a$) and (25). (Details are available on request.) A large number of solutions exist, but all appear to imply very weak personal performance incentives. The *largest* solution for $\beta$ is .0053, which obtains with extremely noisy personal performance evaluation: $\lambda = .001$. Consequently, the model can fit the data, but only with trivial performance incentives.

Is there any value of the personal performance parameter $\beta$ that implies the estimated standard deviation of pay, as well as the estimated team incentives? To answer this, I search for values of $\beta$ that satisfy equation (25) with $\sigma_w = \$83{,}300$ and equation (23) with $\gamma = .0000329$. This amounts to replacing equation (11$a$) by equation (25). (Details are available on request.) There exists a standard deviation of personal performance $\sigma$ for any reliability statistic $\lambda$ such that $\beta$ equals—for the benchmark case of $r = 1 \times 10^{-5}$ and $c_1 = 4 \times 10^{-8}$—approximately .47. For instance, if $\lambda = .15$, then $\sigma = \$105{,}000$ generates $\beta = .468$. So the data are consistent with strong incentives.[15]

Overall, the calibration indicates that the magnitude of team incentives is not a great mystery. With noisy personal performance evaluation, team incentives fall to the neighborhood of Jensen and Murphy's estimate. Nevertheless, the team incentives model is not consistent with additional evidence. If the model's implication regarding the ratio of team and personal incentives is maintained, the calibrated variance of pay understates its empirical counterpart. Yet a conclusion that top executives face weak incentives would be

[14]The standard deviation of personal performance $\sigma$ is fixed at \$700,000 in Table 2. Table 3 displays how $\beta$, $\gamma$, and $\sigma_w$ vary with $\sigma$, holding $r$ and $\lambda$ fixed. The results indicate that varying $\sigma$ does not align the theory and evidence. However, that team performance incentives increase with personal performance risk is consistent with strong team incentives at the top of an organization.

[15]This last calibration uses the equations describing the solution that deters adverse selection. But the extension to adverse selection does not align the theory with the evidence. Parameters that solve this last calibration would lead employers to choose (by equation (11$a$)) even stronger personal incentives, so adverse selection would not pose a problem.

TABLE 3

**Calibration of Executive Compensation**[a]
Varying Personal Performance Risk

| Standard Deviation of Personal Performance ($\sigma$) | Personal Performance Parameter ($\beta$) | Team Performance Parameter ($\gamma$) | Standard Deviation of Pay ($\sigma_w$) |
|---|---|---|---|
| 50,000 | .993 | .000000 | 128,244 |
| 100,000 | .974 | .000001 | 251,492 |
| 200,000 | .904 | .000005 | 466,624 |
| 300,000 | .806 | .000010 | 624,673 |
| 400,000 | .701 | .000016 | 723,919 |
| 500,000 | .600 | .000021 | 774,594 |
| 600,000 | .510 | .000026 | 790,404 |
| 700,000 | .434 | .000030 | 783,555 |
| 800,000 | .369 | .000033 | 763,157 |
| 900,000 | .316 | .000036 | 735,390 |
| 1,000,000 | .273 | .000039 | 704,198 |

[a]Notes: The marginal cost of effort function is $C'(e) = c_0 + c_1 e$, with $c_1 = 4 \times 10^{-8}$. The coefficient of absolute risk aversion $r$ is set to $1 \times 10^{-5}$. The reliability statistic, $\lambda \equiv \sigma^2/(\sigma^2 + \sigma_\varepsilon^2)$, is set to .15. The standard deviation of firm value is set to $200 million.

premature. With the ratio restriction relaxed, strong calibrated personal performance incentives are consistent with the variance of pay, as well as the strength of team incentives. The calibration's only failure is in matching the ratio of team to personal incentives.

## V. Conclusions

The purpose of this paper has been to answer the question: Why not team incentive contracts? I have drawn my answers from the effects of risk aversion, firm size, signals of personal performance, sabotage, collusion, and adverse selection. In generalizing the contracting environment to include these features, I have dropped the premise of a strong link between individual compensation and firm performance—the link might be quite weak—to investigate how the strength of the link varies with economic variables.

The link between individual compensation and firm performance is predicted to be stronger where: (a) workers are less risk averse and production less risky; (b) effort supply is more elastic; (c) firms are smaller; (d) measures of individual performance are noisier; (e) employer sabotage would not be a problem, such as where ownership is separated from control; (f) collusion would not be successful, such as where workers do not interact and have difficulty in monitoring each others' efforts; and (g) adverse selection would not result, such as if workers are fairly homogeneous (conditional on observable traits) or have little informational advantage over firms in accessing their talents.

The application to executive compensation is enlightening. For the model with noisy personal performance evaluation, calibrated team incentives are quite small—about the same size as the motivating estimate from Jensen and Murphy (1990). Yet calibrated personal performance incentives are fairly strong, suggesting that rampant shirking among CEOs does not exist. The calibration's only failure is in matching the ratio of team to personal incentives.

## Appendix

Familiar comparative statics results include that the performance parameters and effort are increasing functions of product price $p$ and decreasing functions of the degree of risk aversion $r$ and the slope of effort supply $C''$. Several results are more novel.

Since increasing firm size increases the risk from total output variation, effort and team incentives are decreasing functions of $n$, but personal performance incentives increase in $n$.

$$\frac{\partial \beta^*}{\partial n} = \left(1 + rC''\sigma^2\right)\gamma^* \Big/ (n-1)D \geq 0 \tag{26a}$$

$$\frac{\partial \gamma^*}{\partial n} = -\left[1 + rC''\left(\sigma^2 + \sigma_\phi^2\right)\right]\gamma^* \Big/ (n-1)D \leq 0 \tag{26b}$$

$$\frac{\partial e^*}{\partial n} = -r\sigma_\phi^2\gamma^* \Big/ (n-1)D \leq 0 \tag{26c}$$

where $D$ is the denominator in equations (11$a$) and (11$b$).

The personal performance parameter $\beta^*$ and effort $e^*$ are decreasing in the variance of the noise $\sigma_\phi^2$, but team incentives are increasing in $\sigma_\phi^2$.

$$\frac{\partial \beta^*}{\partial \sigma_\phi^2} = -\left(1 + rC''\sigma^2 n\right)\gamma^* \Big/ \sigma_\phi^2 D \leq 0 \tag{27a}$$

$$\frac{\partial \gamma^*}{\partial \sigma_\phi^2} = \left(1 + rC''\sigma^2\right)\gamma^* \Big/ \sigma_\phi^2 D \geq 0 \tag{27b}$$

$$\frac{\partial e^*}{\partial \sigma_\phi^2} = -J\gamma^* \Big/ D \leq 0. \tag{27c}$$

In standard fashion, effort is decreasing in $\sigma^2$; however, the personal performance parameter is not necessarily negatively related to $\sigma^2$.

$$\frac{\partial \beta^*}{\partial \sigma^2} = -\left\{(n-1)rC''\sigma^4 - \sigma_\phi^2\right\}\gamma^* \Big/ \sigma^2\sigma_\phi^2 D \gtrless 0 \tag{28a}$$

$$\frac{\partial \gamma^*}{\partial \sigma^2} = -\left\{1 + rC''(\sigma^2 + \frac{n}{n-1}\sigma_\phi^2\right\}\gamma^* \Big/ \sigma^2 D \leq 0 \tag{28b}$$

$$\frac{\partial e^*}{\partial \sigma^2} = -\left\{\frac{1+J}{J}r\sigma^2 + \frac{n}{n-1}\sigma_\phi^2\right\}\gamma^* \Big/ \sigma^2 D^2 \leq 0. \tag{28c}$$

If the measurement error component is large, personal performance incentives are an increasing function of the variance of the production shock, as the optimal contract shifts weight from $\gamma^*$ to $\beta^*$.

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