

The rise of individual performance pay*

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Abstract

Why does individual performance pay seem to prevail in human-capital-intensive industries where teamwork is so common? We present a model that aims to explain this. In a repeated game model of relational contracting, we analyze the conditions for implementing peer-dependent incentive regimes when agents possess indispensable human capital. We show that the larger the share of values that the agents can hold-up, the lower is the implementable degree of peer-dependent incentives. In a setting with team effects - complementary tasks and peer pressure, respectively - we show that while group-based incentives are optimal if agents are dispensable, it may be costly, and in fact suboptimal, to provide team incentives once the agents become indispensable.

JEL Classification: D23, J33, L14

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1 Introduction

Firm value is increasingly dependent on human capital. The share of physical capital in publicly traded corporations has dramatically decreased the last 30 years (see e.g. Blair and Kochan, 2000). At the same time we observe

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a higher degree of individual performance pay in modern corporations (see e.g. Brown and Heywood, 2002). Are these trends related? Several studies indicate so. Long and Shields (2005) find that individual performance pay is more likely to be found in firms with highly educated employees, while studies by Kato (2002) and Torrington (1993) indicate that workers with more education are particularly interested in receiving rewards tailored to individual performance. Tremblay and Chenevert (2004) find that high-tech firms (characterized by a high percentage of scientists and engineers in the workforce) are more likely to use individual performance pay, but not group pay, and a recent study by Barth et al. (2006) indicates that group-based incentives is decreasing for those with higher education, while it is increasing for blue-collar workers. Individual performance pay, on the other hand, is found to be strongly associated with firms with a highly educated workforce.¹

Why is this? Barth et al. (2006) suggest that the quality and effort of high-skilled workers have larger impacts on productivity than the quality and effort of other groups of workers. They lend support from Brown (1990) who argues that in high-skilled jobs, worker output is more sensitive to worker quality compared to jobs requiring less skill. In our view, these are plausible, but not satisfactory explanations. Group-based incentives are desirable when teamwork is important, when there exists peer pressure, or when it is difficult to identify each worker's contribution to firm value. It is hard to see that this applies less to educated employees. In fact, several HR scholars have argued that knowledge-intensive organizations' emphasis on innovation, teamwork and projects calls for group-based incentives (see e.g. Balkin and Bannister, 1993).

In this paper we recognize two features of human capital that necessitate a high degree of individual performance pay in knowledge-intensive industries. First, the true performance of educated employees is often difficult to verify by third parties. Objective measures of performance seldom exists, and even if they do, looser assessments of performance also affect compensation (see e.g. MacLeod, 2003). Consequently, incentive contracts specifying criteria for performance pay are seldom fully protected by the court. Second, human capital blurs the allocation of ownership rights. According to the standard view of ownership, it is the owner of an asset who has residual control right over the asset; that is "the right to decide all usages of the asset in any way not inconsistent with a prior contract, custom or law" (Hart, 1995). If the asset involved in the worker's production is his own mind and knowledge, then

¹In addition, several studies show that firms with low union coverage are more willing to use individualized incentive schemes (see e.g. Brown, 1990; Parent, 2002; and Long and Shields, 2005), and union coverage is lower among high-skilled workers (Acemoglu et al. 2001).

he also is to decide all non-contractual usages. An indispensable "knowledge worker" can therefore threaten to walk away with ideas, clients, techniques etcetera. As noted by Liebeskind (2000), human-capital-intensive firms must induce their employees to stay around long enough so that the firm can establish some intellectual property rights with respect to the ideas generated by these employees, or else these firms run the risk of being expropriated or held-up by their own employees.²

Why do these two features - incomplete contracts and indispensable human capital - prepare the way for individual performance pay? In other words: Why is it difficult to implement *peer-dependent incentives* when performance is unverifiable and workers possess residual control rights? The answer is intuitive when we think of the incentives facing an agent who is a full residual claimant: He simply gets the values he has produced; the market incentives are independent from what other agents produce. Hence, if a principal wants to implement a peer-dependent incentive contract, she faces a problem if the agents have residual control rights. With relative performance evaluation (RPE) an agent is not paid well if his peer performs better, while with joint performance evaluation (JPE) he is not paid well if his peers' performance is poor. This peer-dependence may lead to contract breach: an agent who is paid a low bonus after realizing a high output, has incentives to hold-up his output and renegotiate payments. Of course, a hold-up strategy is only possible if the agent actually is able to prevent the principal from realizing the agent's value added ex post production. But if hold-up *is* possible, then RPE and JPE schemes are more susceptible to hold-up than incentive schemes based on independent performance evaluation (IPE).

The parties can mitigate the hold-up problem through repeated interaction, i.e. through self-enforcing relational contracting³ (also called implicit contracting) where contract breach is punished, not by the court, but by the parties who can refuse to cooperate after a deviation. But since a hold-up will be regarded as a deviation from such a relational contract, the self-enforcing range of the contract is limited by the hold-up problem. And since the hold-

²It should be noted that indispensability is mainly achieved through investments in firm-specific human capital. Hence, a worker who possesses indispensable human capital is not necessarily highly educated, and education does not guarantee indispensability. However, specific human capital is strongly associated with high levels of formal education (see Blundell et al., 1999).

³Influential models of relational contracts include Klein and Leffler (1981), Shapiro and Stiglitz (1984), Bull (1987), Kreps (1990), Baker, Gibbons and Murphy (1994, 2002), Schmidt and Schnitzer (1995). MacLeod and Malcolmson (1989) generalize the case of symmetric information, while Levin (2003) makes a general treatment of relational contracts with asymmetric information, allowing for incentive problems due to moral hazard and hidden information.

up problem is most severe in JPE and RPE, we can expect a larger fraction of IPE when hold-up is feasible.

Is this a problem? Yes, the literature has pointed out numerous reasons for why it may be efficient to tie an agent's compensation to the performance of the agent's peers. By tying compensation to the agent's relative performance, the principal can filter out common noise so that compensation to the largest possible extent is based on real effort, not random shocks that are outside the agent's control (see Holmström, 1982; and Mookherjee, 1984). With RPE's special form, rank-order tournaments, the agents are also completely insulated from the risk of common negative shocks (see Lazear and Rosen, 1981; Nalebuff and Stiglitz, 1983; Green and Stokey, 1983). Moreover, tournaments need only rely on ordinal performance measures. It may thus be easier and less costly to measure relative than absolute performance (Lazear and Rosen, 1981). In addition, it may be easier for the principal to *commit* to tournament schemes if output is not verifiable, since the number of 'high bonuses' are smaller than under independent contracts (Carmichael, 1983; Malcomson, 1984; Levin, 2002).

There are also obvious arguments for tying compensation to the joint performance of a group of agents. Joint performance evaluation can promote cooperation since an agent is rewarded if his peers perform well (see e.g. Holmström and Milgrom, 1990; Itoh 1993; and Macho-Stadler and Perez-Castrillo, 1993). JPE can also provide implicit incentives not to shirk (or exert low effort), since shirking may have social costs (as in Kandel and Lazear, 1992), or induce other agents to shirk, which again reduces the shirking agent's expected compensation (as in Che and Yoo, 2001).

But both RPE and JPE have drawbacks. JPE may be susceptible to free-riding (see e.g. Alchian and Demsetz, 1972; and Holmström, 1982), while RPE is susceptible to collusion (see e.g. Mookherjee, 1984). RPE may also induce sabotage and discourage cooperation (see Lazear, 1995, for a discussion of the costs and benefits of RPE and JPE).

In this paper we provide a new rationale for independent performance evaluation. We begin (Section 2) by analyzing a simple model where IPE, RPE and JPE are equally efficient when output is verifiable. With unverifiable output, no incentive contracts are viable in the static setting. In the repeated setting, however, incentive contracts are viable for sufficiently large discount factors. A main result from this section then goes as follows: the maximum dependence between agent i 's bonus and agent j 's output that the principal can implement, decreases with the share of values that the agents can hold-up ex post, and for a sufficiently large share only IPE remains feasible.

We then (Section 3) demonstrate the importance of agent-hold up in

a setting with team effects. We consider two cases: complementary tasks and peer pressure. We show that a stark JPE contract is optimal only if the agents' hold-up power is sufficiently low. In the case of complementary tasks, the optimal implementable scheme becomes less JPE and more IPE the larger the share of values the agents can hold-up. In the case of peer pressure, any JPE scheme becomes suboptimal once the relational contract constraints bind. The reason is that once the outside market becomes tempting, the principal can no longer use JPE to exploit peer pressure effects, but has to compensate the agents for any disutility that team incentives provide.

Broadly speaking, our contribution is to consider the effect of residual control rights in a multiagent moral hazard model. In the vast literature on multiagent moral hazard it is (implicitly) assumed that residual control rights are exclusively in the hands of the principal. And in the growing literature dealing with optimal allocation of control rights, the multiagent moral hazard problem is not considered. (This literature begins with Grossman and Hart, 1986; and Hart and Moore, 1990,⁴ who analyze static relationships. Repeated relationships are analyzed in particular by Halonen, 2002; and Baker, Gibbons and Murphy, 2002). Our paper also contributes to the literature by introducing other-regarding preferences and team technology in a relational contracting set-up.

The paper proceeds as follows. In Section 2 we present the model and deduce the optimal relational incentive contract. Section 3 introduces team effects, while Section 4 offer some concluding remarks.

2 The Model

Consider an economic environment consisting of one principal and two identical agents who each period produce either high, Q_H , or low, Q_L , values for the principal. Each agent's effort level can be either high or low, where high effort has a disutility cost of c and low effort is costless. The principal can only observe the realization of the agents' output, not the level of effort they choose. Similarly, agent i can only observe agent j 's output, not his effort level.⁵

The agents' outputs depend on efforts. Output realizations are stochasti-

⁴Although Hart and Moore (1990) analyze a model with many agents, they do not consider the classical moral hazard problem that we address, where a principal can only observe a noisy measure of the agents' effort.

⁵Whether or not the agents can observe each others effort level is not decisive for the analysis presented. However, by assuming that effort is unobservable among the agents, we do not need to model repeated peer monitoring.

cally independent, but each agent's success probability is generally assumed to depend on the agent's own as well as his partner's effort. We will see that technological complementarities between the agents, in the sense that an agent's success probability is strictly increasing in his partner's effort, is an argument for making use of JPE in this setting.

In a first version of the model we will however assume that there are no such technological externalities between the agents. While this assumption removes the rationale for using peer-dependent incentive schemes (and thus makes JPE, RPE and IPE equally effective if output is verifiable), it allows us to introduce and analyze the implications of non-verifiability and agent hold-up in a simple setting. The point of this first version of the model is to show that agent hold-up may severely limit the range of incentive schemes that can be implemented under relational contracting. In this section we thus assume that the probability for agent i of realizing Q_H depends only on the agent's own effort. The probability is q_H if effort is high and q_L if effort is low, where $1 > q_H > q_L \geq 0$.

It is assumed that all parties are risk neutral, but that the agents are subject to limited liability: the principal cannot impose negative wages.⁶ Ex ante outside options are normalized to zero. The participation constraint then holds trivially by the limited liability assumption.

We assume that if the parties engage in an incentive contract, agent i receives a bonus vector $\boldsymbol{\beta} \equiv (\beta_{HH}^i, \beta_{HL}^i, \beta_{LH}^i, \beta_{LL}^i)$ where the subscripts refer to respectively agent i and agent j 's realization of Q_i , ($i = H, L$).

Let agents i and j choose efforts $k \in \{H, L\}$ and $l \in \{H, L\}$ respectively. Agent i 's expected wage is then

$$\pi(k, l, \boldsymbol{\beta}^i) \equiv q_k q_l \beta_{HH}^i + q_k (1 - q_l) \beta_{HL}^i + (1 - q_k) q_l \beta_{LH}^i + (1 - q_k) (1 - q_l) \beta_{LL}^i \quad (1)$$

For each agent, a wage scheme exhibits joint performance evaluation if $(\beta_{HH}, \beta_{LH}) > (\beta_{HL}, \beta_{LL})$ ⁷. (For the most part, we suppress agent-notation in superscript since the agents are identical.) In this case $\pi(k, H, \boldsymbol{\beta}) > \pi(k, L, \boldsymbol{\beta})$, so an agent's work yields positive externalities to his partner. A wage scheme exhibits relative performance evaluation if $(\beta_{HH}, \beta_{LH}) < (\beta_{HL}, \beta_{LL})$. In this case $\pi(k, H, \boldsymbol{\beta}) < \pi(k, L, \boldsymbol{\beta})$, so an agent's work generates a negative externality for his partner. A wage scheme exhibits independent performance evaluation if $(\beta_{HH}, \beta_{LH}) = (\beta_{HL}, \beta_{LL})$, which implies $\pi(k, H, \boldsymbol{\beta}) = \pi(k, L, \boldsymbol{\beta})$, so an agent's work has no impact on his partner.

⁶Limited liability may arise from liquidity constraints or from laws that prohibit firms from extracting payments from workers.

⁷The inequality means weak inequality of each component and strict inequality for at least one component.

This set-up follows Che and Yoo's (2001). As shown by these authors, peer-monitoring is a rationale for making use of peer-dependent incentives such as JPE. We introduce and explore instead (in the next section) technological complementarities and peer pressure in this setting. We also extend their model by assuming non-verifiable output, and that agents are able to hold-up values ex post.⁸

2.1 Optimal contract when output is verifiable

As a benchmark, we first consider the least cost incentive contract when output is verifiable. For an incentive contract to be viable, the value of high effort must weakly exceed the cost of effort, that is

$$\Delta q \Delta Q \geq c \quad (2)$$

where $\Delta q = q_H - q_L$ and $\Delta Q = Q_H - Q_L$. Assuming that (2) holds, the principal's problem is to minimize the wage payments subject to the constraints that the agents must be induced to yield high effort. A contract β induces both agents to work if

$$\pi(H, H, \beta) - c \geq \pi(L, H, \beta) \quad (3)$$

The left hand side (LHS) shows the expected wage from exerting high effort, while the right hand side (RHS) shows the expected wage from exerting low effort. The condition ensures that high effort from both agents is an equilibrium, given the contract β . The agents' equilibrium is unique if high effort is a dominant strategy, i.e. if $\pi(H, L, \beta) - c \geq \pi(L, L, \beta)$ holds in addition to (3). We will discuss uniqueness below.

The principal solves

$$\min_{\beta \geq \mathbf{0}} \pi(H, H, \beta), \text{ subject to (3)} \quad (4)$$

The incentive compatibility (IC) constraint (3) can be written

$$q_H \beta_{HH} + (1 - q_H) \beta_{HL} - q_H \beta_{LH} - (1 - q_H) \beta_{LL} \geq \frac{c}{\Delta q} \quad (\text{IC})$$

Now, by IC and the definition of π we have

$$\begin{aligned} \pi &= q_H [q_H \beta_{HH} + (1 - q_H) \beta_{HL}] + (1 - q_H) [q_H \beta_{LH} + (1 - q_H) \beta_{LL}] \quad (5) \\ &\geq q_H \frac{c}{\Delta q} + [q_H \beta_{LH} + (1 - q_H) \beta_{LL}] \end{aligned}$$

⁸Kvaløy and Olsen (2006) analyze a multilateral relational contract with repeated peer-monitoring. But team technology, peer pressure and agent hold-up is not considered in that model.

From this inequality and limited liability ($\beta_{LH}, \beta_{LL} \geq 0$) we obtain:

Lemma 1 *If output is verifiable, the minimal wage cost for the principal is $\pi_m = q_H \frac{c}{\Delta q}$. Any wage scheme that has $\beta_{LH} = \beta_{LL} = 0$ and satisfies IC with equality is optimal.*

Remark. As noted above, a contract will induce high effort from both agents as a unique equilibrium in the agents' game if in addition to IC it satisfies $\pi(H, L, \beta) - c \geq \pi(L, L, \beta)$. It can be shown (see the appendix) that for any contract that satisfies IC with equality, this condition will hold if the contract is RPE or IPE, but it will not hold if the contract is JPE. For the contracts given in the lemma, only the RPE or IPE contracts will thus yield uniqueness. A contract that is JPE ($\beta_{HH} > \beta_{HL}$) yields two equilibria, with efforts (H,H) and (L,L), respectively. But as shown in the appendix, the latter yields a smaller payoff than the former, since we have $\pi(H, H, \beta) - c > \pi(L, L, \beta)$. Thus it seems reasonable to assume that also a JPE contract will induce high effort from both agents.

2.2 Relational contracting

Assume now that output is non-verifiable. The incentive contract must then be self-enforcing, and thus 'relational' by definition. We consider a multi-lateral punishment structure where any deviation by the principal triggers low effort from *both* agents. The principal honors the contract only if both agents honored the contract in the previous period. The agents honor the contract only if the principal honored the contract with both agents in the previous period. A natural explanation for this is that the agents interpret a unilateral contract breach (i.e. the principal deviates from the contract with only one of the agents) as evidence that the principal is not trustworthy (see Bewley, 1999, and Levin, 2002).⁹

The relational incentive contract is self-enforcing if the present value of honoring is greater than the present value of renegeing. Ex post realizations of values, the principal can renege on the contract by refusing to pay the promised wage, while the agents can renege by refusing to accept the promised wage, and instead hold-up values and renegotiate what we can call a spot contract. The spot price is denoted ηQ_i . If values accrue directly to the principal, then $\eta = 0$. But if the agent is able to hold-up values ex-post,

⁹Modelling multilateral punishments is also done for convenience. Bilateral punishments will not alter our results qualitatively.

then η is determined by bargaining power, outside options and the ability to hold-up values. Assume that there exists an alternative market for the agents' output, and that the agents are able to independently realize values θQ_i , $\theta \in (0, 1)$ ex post.¹⁰ If we assume Nash bargaining between principal and agents, each agent will then receive θQ_i plus a share γ from the surplus from trade i.e. $\theta Q_i + \gamma(Q_i - \theta Q_i) = \eta Q_i$ where $\eta = \gamma + \theta(1 - \gamma)$.

It should be noted that the ability to hold-up values rests on the assumption that agents become indispensable *in the process* of production (as in e.g. Halonen, 2002). We do not analyze the incentives to invest in firm-specific human capital (as in e.g. Kessler and Lülfsmann, 2006). Rather, we just assume that agents become indispensable ex post, and then focus on how this affects the multiagent moral hazard problem. We thus follow the relational contracting literature, and abstract from human capital *accumulation*. The level of θQ_i and ηQ_i is therefore assumed to be exogenously given and constant each period. This also allows us to concentrate on stationary relational contracts.¹¹

The parties are assumed to play trigger strategies. If the principal reneges on the relational contract, both agents insist on spot contracting forever after. And vice versa: if one of the agents (or both) renege, the principal insists on spot contracting forever after.

For a relational contract to dominate a spot contract, the agents cannot have incentives to exert high effort in a spot contract, that is

$$\eta \Delta q \Delta Q < c \tag{6}$$

Hence, if (2) and (6) hold, an incentive contract inducing both agents to exert high effort dominates a spot contract. Throughout the paper it will be assumed that both these conditions hold, so that we have

$$\eta < \frac{c}{\Delta q \Delta Q} \leq 1.$$

2.2.1 Contract constraints

Consider now the conditions for the incentive contract to be self-enforcing, i.e. the conditions for implementing a *relational incentive contract*. The parties decide whether or not to honor the incentive contract ex post realization of

¹⁰The parameter θ depends on the specificity of the agents' value-added. The higher specificity, the lower is θ .

¹¹In a stationary contract, the principal promises the same contingent compensation in each period.

output, but ex ante bonus payments. The principal will honor the contract if

$$\begin{aligned} & -\beta_{ij} - \beta_{ji} + \frac{2\delta}{1-\delta} [Q_L + q_H \Delta Q - \pi(H, H, \boldsymbol{\beta})] \\ \geq & -\eta(Q_i + Q_j) + \frac{2\delta}{1-\delta} [Q_L + q_L \Delta Q - S], \quad i, j \in \{H, L\} \end{aligned}$$

where $S = \eta(Q_L + q_L \Delta Q)$ is the expected spot price. The LHS of the inequality shows the principal's expected present value from honoring the contract, while the RHS shows the expected present value from renegeing. We see that the constraint binds when $\beta_{ij} + \beta_{ji} - \eta(Q_i + Q_j)$ is maximal. We can thus write the condition as

$$\begin{aligned} \max \{ & 2\beta_{HH} - 2\eta Q_H, \beta_{HL} + \beta_{LH} - \eta(Q_H + Q_L), 2\beta_{LL} - 2\eta Q_L \} \\ & \leq \frac{2\delta}{1-\delta} [\Delta q \Delta Q + S - \pi(H, H, \boldsymbol{\beta})] \quad (\text{EP}) \end{aligned}$$

Agent i will honor the contract if

$$\beta_{ij} + \frac{\delta}{1-\delta} (\pi(H, H, \boldsymbol{\beta}) - c) \geq \eta Q_i + \frac{\delta}{1-\delta} S, \quad i, j \in \{H, L\}$$

where similarly the LHS shows the agent's expected present value from honoring the contract, while the RHS shows the expected present value from renegeing. The constraint binds when $\beta_{ij} - \eta Q_i$ is minimal. We can thus write the condition as

$$\begin{aligned} \min \{ & \beta_{HH} - \eta Q_H, \beta_{HL} - \eta Q_H, \beta_{LH} - \eta Q_L, \beta_{LL} - \eta Q_L \} \\ & \geq \frac{\delta}{1-\delta} [S - \pi(H, H, \boldsymbol{\beta}) + c] \quad (\text{EA}) \end{aligned}$$

2.2.2 Optimal relational contract

To minimize expected wage costs, the principal will solve

$$\begin{aligned} & \min \pi(H, H, \boldsymbol{\beta}) \\ & \text{subject to (IC), (EP) and (EA)} \end{aligned}$$

Now, we showed that IC implies (5), and from this relation and EA (applied to β_{LH} and β_{LL}) we have

$$\pi \geq q_H \frac{c}{\Delta q} + \eta Q_L + \frac{\delta}{1-\delta} [S - \pi + c]$$

Collecting terms involving π and substituting for $S = \eta(Q_L + q_L \Delta Q)$ we obtain

$$\pi \geq q_H \frac{c}{\Delta q} + \eta Q_L - \delta \left(\frac{c}{\Delta q} - \eta \Delta Q \right) q_L$$

Since IC and limited liability ($\beta_{LH}, \beta_{LL} \geq 0$) implies $\pi \geq q_H \frac{c}{\Delta q}$, we see that we have the following lower bound for the wage cost

$$\pi \geq q_H \frac{c}{\Delta q} + \max\{0, \eta Q_L - \delta \left(\frac{c}{\Delta q} - \eta \Delta Q \right) q_L\} = \pi_{\min}$$

The last term in π_{\min} reflects the influence of the enforceability conditions (EA) for the agent. When this term is positive, it is impossible to implement and enforce a relational contract where the agent is paid $\beta_{LH} = \beta_{LL} = 0$ for a low outcome, and the wage cost for the principal will therefore exceed the cost for the verifiable case. Higher wages ease implementation by making it less tempting for the agent to break the relationship by offering his value-added to outsiders.

The additional cost is increasing in η , the share of the value that the agent can hold-up ex post. The cost is naturally decreasing in δ , since higher discount factors ease implementation. We will here restrict attention to cases where the hold-up problem is serious in the sense that the cost is positive for all $\delta < 1$. This will be the case when the share parameter η is sufficiently large, more precisely when it satisfies¹²

$$\eta \geq \eta_0 = \frac{c q_L}{\Delta q} \frac{1}{Q_L + \Delta Q q_L}$$

The derivation of the lower bound π_{\min} above shows that in order to minimize the additional cost associated with non-verifiability and agent hold-up, the principal must set $\beta_{LH} = \beta_{LL}$, i.e. ensure that an agent's pay for low output is independent of the other agent's output. Each agent effectively receives a fixed wage $\beta_{LH} = \beta_{LL}$ independent of outputs, and then some additional bonus ($\beta_{Hj} - \beta_{Lj}$) is paid if he realizes high output. This additional bonus may depend on his peer's outcome, but as we shall see the scope for such dependence is quite limited.

The limits are imposed in part by the dynamic enforceability constraints (EA). We have seen that to achieve the minimal wage cost these constraints must be binding for the outcomes LL and LH. The derivation of π_{\min} also

¹²Note that $\eta_0 \Delta q \Delta Q < c$, so (6) is not violated.

shows that the 'fixed wage' associated with these outcomes ($\beta_{LH} = \beta_{LL}$) generates the additional cost term in the expression for π_{\min} , and that we hence have (for $\eta > \eta_0$):

$$\beta_{LH} = \beta_{LL} = \eta Q_L - \delta\left(\frac{c}{\Delta q} - \eta\Delta Q\right)q_L > 0 \quad (8)$$

Since the enforceability constraint (EA) is binding for these two bonuses, it follows that we can write this constraint for the other bonuses in the following form:

$$\min\{\beta_{HH} - \eta\Delta Q, \beta_{HL} - \eta\Delta Q\} \geq \beta_{LH} = \beta_{LL} \quad (\text{EA}')$$

This relation says that the bonus increments for high output $\beta_{HH} - \beta_{LH}$ and $\beta_{HL} - \beta_{LL}$ must both exceed $\eta\Delta Q$, which is the additional value of high output for the agent outside the relationship. At the same time the bonuses must be incentive compatible with high effort, and to minimize costs they must satisfy IC with equality, which is to say that we must have

$$q_H(\beta_{HH} - \beta_{LH}) + (1 - q_H)(\beta_{HL} - \beta_{LL}) = \frac{c}{\Delta q} \quad (\text{IC}')$$

Note that an IPE scheme with $\beta_{Hj} - \beta_{Lj} = \frac{c}{\Delta q}$ will certainly fulfill both constraints EA' and IC', given that we have assumed $\frac{c}{\Delta q} > \eta\Delta Q$, see (6). The constraints imply that to generate minimal costs and be implementable a scheme cannot deviate too much from IPE. Before discussing that further, we summarize the findings so far in the following lemma.

Lemma 2 *For $\eta > \eta_0$ the minimal wage cost that fulfills IC and EA is obtained when (i) IC binds and (ii) the dynamic enforceability constraint EA binds for outcomes LH and LL. The wage scheme satisfies (8), EA' and IC', and the minimal cost is*

$$\pi_{\min} = q_H \frac{c}{\Delta q} + \eta Q_L - \delta\left(\frac{c}{\Delta q} - \eta\Delta Q\right)q_L$$

Figure 1 provides an illustration.

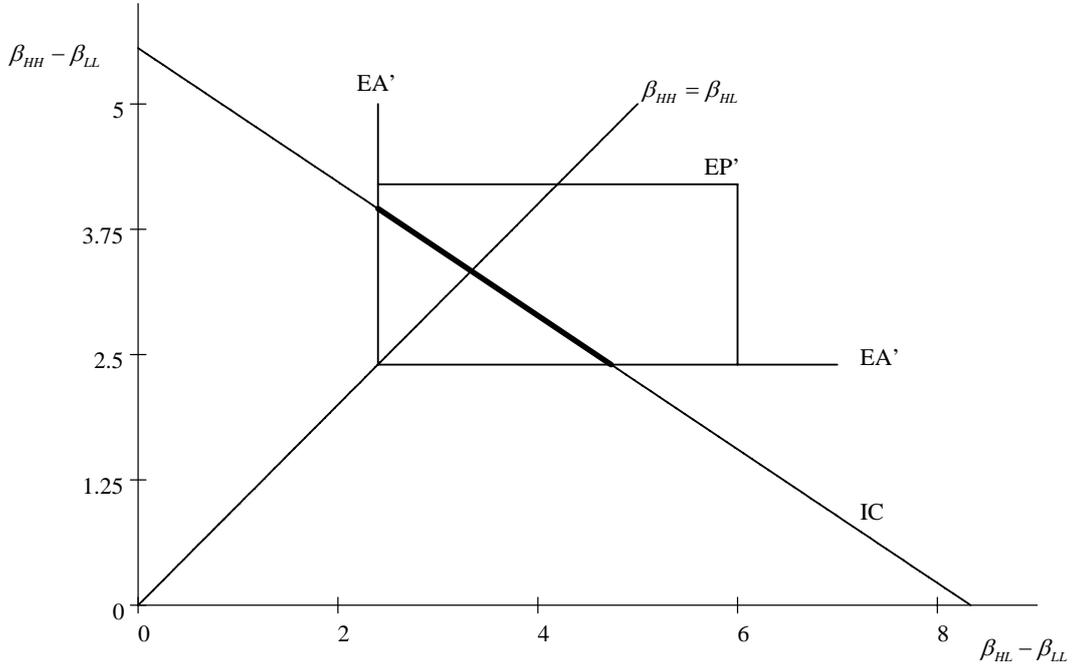


Figure 1

The figure depicts the IC constraint and the "reduced form" dynamic enforceability constraints for the agents (EA') as functions of the bonus increments $\beta_{HL} - \beta_{LL}$ and $\beta_{HH} - \beta_{LH}$ (where $\beta_{LH} = \beta_{LL}$). Here points above, on and below the diagonal represent, respectively, JPE, IPE and RPE contracts. The figure illustrates that only a limited set of contracts on IC satisfies the agents' enforceability constraints.

To be fully feasible a contract must also satisfy the dynamic enforceability constraint for the principal (EP). As we will now demonstrate, this constraint can be represented in reduced form as the curve marked EP' in Figure 1. Using (8), EA' and substituting for S and $\pi = \pi_{\min}$ in EP, we see that this constraint can be written

$$\max \{2(\beta_{HH} - \beta_{LH} - \eta\Delta Q), (\beta_{HL} - \beta_{LL} - \eta\Delta Q)\} \leq \frac{2\delta}{1-\delta} [\Delta q\Delta Q - c] \quad (\text{EP}')$$

This "reduced form" EP constraint can evidently be represented as the curve marked EP' in Figure 1. The curve has a kink at $\beta_{HH} - \beta_{LH} = \frac{1}{2}(\beta_{HL} - \beta_{LL} + \eta\Delta Q)$, and its position depends on δ . For given bonuses, the constraint requires that the discount factor δ must be sufficiently large to guarantee implementability. Conversely, for given δ the constraint limits the set of bonuses that can be implemented; in particular we see that the bonus increments $\beta_{Hj} - \beta_{Lj}$ cannot be too large.

The minimal discount factor $\delta = \widehat{\delta}$ for which a bonus scheme satisfying IC and EA' also satisfies EP' is obtained when the kink of the EP' curve in Figure 1 is positioned on IC, i.e. when IC, EP' and $2(\beta_{HH} - \beta_{LH} - \eta\Delta Q) = \beta_{HL} - \beta_{LL} - \eta\Delta Q$ hold jointly. This yields the following condition for $\widehat{\delta}$

$$\frac{1 - \widehat{\delta}}{\widehat{\delta}} = \frac{[\Delta q\Delta Q - c]}{c - \eta\Delta Q\Delta q}\Delta q(2 - q_H) \quad (9)$$

This proves statement (i) in the following proposition. Statement (ii) is proved in the appendix.

Proposition 1 (i) For $\eta \geq \eta_0$ and $\delta \geq \widehat{\delta}$ a wage scheme satisfying (8), IC, EA' and EP' is optimal. The minimal wage cost is given by π_{\min} , and any other implementable wage scheme yields a higher cost. (ii) No wage scheme yielding high effort can be implemented for $\delta < \widehat{\delta}$

In the appendix we also verify that the wage scheme satisfies the following conditions

$$\pi(H, H, \boldsymbol{\beta}) - c \geq S \quad (10)$$

$$\Delta q\Delta Q \geq \pi(H, H, \boldsymbol{\beta}) - S \quad (11)$$

The first shows that the agents' expected payment from the incentive contract exceeds the expected spot price, and the second shows that the principal's expected surplus from the contract exceeds the surplus from spot contracting. All parties are therefore better off with the relational contract than with a spot contract.

Regarding uniqueness in the game played by the agents, the remark that was given for the verifiable case (following Lemma 1) applies also in this case. The high effort equilibrium is unique only if the contract is RPE or IPE. If the contract is JPE, there is also a low effort equilibrium, but it has a strictly lower payoff than the high effort equilibrium.

Proposition 1 shows that an optimal wage scheme satisfies IC and is bounded by the reduced form dynamic implementability constraints EA' and EP'. Consider now variations in η . As η increases (for δ fixed), the curve representing EA' in Figure 1 moves outwards along the 45 degree line with the EP'-curve 'attached to it'. The IC curve remains fixed, and thus a smaller set of bonuses remains admissible. In the limit, as $\eta \rightarrow \frac{c}{\Delta q\Delta Q}$, only a single bonus ($\beta_{HH} = \beta_{HL}$ on IC) remains admissible. Hence, the agents' ability to hold up values ex post calls for incentives based on independent performance evaluation. We have:

Proposition 2 *The maximum dependence between agent i 's bonus and agent j 's output that the principal can implement, decreases with the share of values that the agents can hold-up ex post, and for a sufficiently large share only IPE remains feasible. In particular, for an optimal and feasible wage scheme we have $\beta_{LH} = \beta_{LL}$ and $|\beta_{HH} - \beta_{HL}| \leq (\frac{c}{\Delta q} - \eta\Delta Q)k \rightarrow 0$ as $\eta \rightarrow \frac{c}{\Delta q\Delta Q}$, where $k = \max\{\frac{1}{q_H}, \frac{1}{1-q_H}\}$*

To verify the last assertion in the proposition, note from Lemma 2 that we have $\beta_{LH} = \beta_{LL}$ and $\min\{\beta_{HH}, \beta_{HL}\} \geq \eta\Delta Q + \beta_{LL}$, and then from (IC') $q_H\beta_{HH} + (1 - q_H)\beta_{HL} = \frac{c}{\Delta q} + \beta_{LL}$. Hence it follows that $q_H(\beta_{HH} - \beta_{HL}) \leq \frac{c}{\Delta q} - \eta\Delta Q$ and $(1 - q_H)(\beta_{HL} - \beta_{HH}) \leq \frac{c}{\Delta q} - \eta\Delta Q$. This proves the assertion.

Finally note also that higher η eases implementation of high effort. This is seen in the expression for the critical factor $\hat{\delta}$, which shows that $\hat{\delta} \rightarrow 0$ as $\eta \rightarrow \frac{c}{\Delta q\Delta Q}$.

3 Team incentives

We will now demonstrate the importance of agent-hold up in a setting where there exists team effects. Such effects can take many forms; here we analyze two cases: Complementary tasks and peer pressure.

3.1 Complementary tasks

Assume as before that output realizations are stochastically independent. But assume now that each agent's success probability depends on the agent's own as well as his partner's effort. Let $q(h, k)$ here denote this probability, where h, k refer to own and partner's effort, respectively. For simplicity we assume perfect complements:

$$\begin{aligned} q(H, H) &= \hat{q}_H \\ q(H, L) &= q(L, H) = q(L, L) = q_L, \quad \text{where } q_L < \hat{q}_H \end{aligned}$$

This implies that high effort from one agent is productive only if the other agent also exerts high effort. If both agents exert high effort, the probability for each agent of realizing high output is \hat{q}_H . If not, the probability is q_L , i.e. if agent i exerts high effort, and agent j exerts low effort, the probability for agent i (and agent j) of realizing high output is q_L . In this setting we have:

$$\begin{aligned} \pi(H, H, \boldsymbol{\beta}) &= \hat{q}_H^2\beta_{HH} + \hat{q}_H(1 - \hat{q}_H)(\beta_{HL} + \beta_{LH}) + (1 - \hat{q}_H)^2\beta_{LL} \quad (12) \\ \pi(L, H, \boldsymbol{\beta}) &= q_L^2\beta_{HH} + q_L(1 - q_L)(\beta_{HL} + \beta_{LH}) + (1 - q_L)^2\beta_{LL} \end{aligned}$$

For the case of verifiable output it is here straightforward to see that a stark JPE scheme $(\beta_{HH}, 0, 0, 0)$ can implement high effort at lower cost than an IPE scheme $(\beta, \beta, 0, 0)$. For the former the IC constraint yields $(\hat{q}_H^2 - q_L^2) \beta_{HH} \geq c$ and thus expected costs $\hat{q}_H^2 \frac{c}{\hat{q}_H^2 - q_L^2}$, while for the latter the IC constraint yields $(\hat{q}_H - q_L) \beta_{HH} \geq c$ and thus expected costs $\hat{q}_H \frac{c}{\hat{q}_H - q_L}$. The reason behind this result is as follows: When tasks are complements, low effort from agent i yields a negative externality on agent j . With JPE, the agent is punished for this, i.e. JPE internalizes the externality to some extent. This makes it less costly to implement high effort under JPE than under IPE. Indeed, the stark JPE scheme dominates all other schemes, as we now shall see.¹³

The IC constraint $\pi(H, H, \beta) - c \geq \pi(L, H, \beta)$, can here be written:

$$[\hat{q}_H + q_L] \beta_{HH} + [1 - \hat{q}_H - q_L] (\beta_{HL} + \beta_{LH}) - [2 - \hat{q}_H - q_L] \beta_{LL} \geq \frac{c}{\Delta q} \quad (IC_t)$$

where $\Delta q = \hat{q}_H - q_L$. Substituting for β_{HH} from the IC constraint (IC_t) into the expression for $\pi(H, H, \beta)$ we obtain the following inequality (see the appendix)

$$\pi \geq \frac{\hat{q}_H^2}{\hat{q}_H^2 - q_L^2} c + \frac{p}{2} (\beta_{HL} + \beta_{LH}) + (1 - p) \beta_{LL}, \quad \text{where} \quad p = \frac{2\hat{q}_H q_L}{\hat{q}_H + q_L} < \hat{q}_H \quad (13)$$

It follows from this expression that for verifiable output it is optimal to set $\beta_{HL} = \beta_{LH} = \beta_{LL} = 0$, and thus (from IC_t) $\beta_{HH} = \frac{c}{\hat{q}_H^2 - q_L^2}$. So we have

Proposition 3 *If output is verifiable, and the agents' tasks are perfect complements, there is a unique optimal wage scheme, namely the JPE scheme $\beta = (\beta_{HH}, 0, 0, 0)$ where $\beta_{HH} = \frac{c}{\hat{q}_H^2 - q_L^2}$. The associated minimal wage cost is*

$$\pi_m = \frac{\hat{q}_H^2}{\hat{q}_H^2 - q_L^2} c$$

What happens, then, if output is non-verifiable? Consider first the relational contract constraint EA. Using EA for $\beta_{HL}, \beta_{LH}, \beta_{LL}$ in (13) yields (see the appendix):

$$\pi \geq \frac{\hat{q}_H^2}{\hat{q}_H^2 - q_L^2} c + \frac{q_2}{\hat{q}_H + q_L} q_L \eta \Delta Q + \eta q_L - \delta \left(\frac{c}{\Delta q} - \eta \Delta Q \right) \frac{q_L^2}{\hat{q}_H + q_L} = \pi_m(\delta) \quad (14)$$

¹³The results from this subsection do not hinge on *perfect* complementarity between the agents' tasks. It can be shown that any level of task complementarity yields JPE-optimality in our set-up.

Define η_1 as the smallest value of η that makes the sum of the last two terms in the expression positive for all $\delta \leq 1$, i.e.

$$\eta_1 = \frac{c}{\Delta q} \frac{q_L^2}{(\hat{q}_H + q_L) Q_L + \Delta Q q_L^2}$$

Reasoning as in the previous section we then obtain the following result (see the appendix):

Lemma 3 *For $\eta \geq \eta_1$ the minimal wage cost subject to IC and EA is given by $\pi_m(\delta)$. This is attained when IC binds, and when EA binds for $\beta_{HL}, \beta_{LH}, \beta_{LL}$. The unique bonuses are given by*

$$\begin{aligned} \beta_{HH} &= \beta_{HL} + \frac{1}{\hat{q}_H + q_L} \left(\frac{c}{\Delta q} - \eta \Delta Q \right) > \beta_{HL} = \beta_{LL} + \eta \Delta Q, \\ \beta_{LH} &= \beta_{LL} = \eta Q_L - \delta \left(\frac{c}{\Delta q} - \eta \Delta Q \right) \frac{q_L^2}{\hat{q}_H + q_L} \end{aligned} \quad (15)$$

The wage scheme given in Lemma 3 is JPE, but has a less stark form than the optimal scheme for verifiable output. And we see that the larger is the agent's ex post share η , the closer the scheme is to an IPE scheme; specifically we see that $\beta_{HH} - \beta_{HL} \rightarrow 0$ as $\eta \rightarrow \frac{c}{\Delta q \Delta Q}$.

Figure 1 can again be used as an illustration. Note that in the model of the previous section (with no team effects) the iso-cost lines for $\pi(H, H, \beta)$ have the same slope as IC in the figure, namely $\frac{1-q_H}{q_H}$. In the present model the iso-cost lines would be steeper than IC in the figure, the slopes would be $\frac{1-\hat{q}_H}{\hat{q}_H}$ and $\frac{1-\hat{q}_H-q_L}{\hat{q}_H+q_L}$, respectively. (This follows from (12) and IC_t , respectively, when $\beta_{LH} = \beta_{LL}$.) Seeking the lowest cost, the principal is constrained by the EA constraint, and hence is lead to the contract represented by the upper intersection point of IC and EP' in the figure. This corresponds to the contract given in Lemma 3. As the agent's ex post share η increases, this point moves towards the diagonal, i.e. towards an IPE contract.

To be implementable, a wage scheme must also satisfy EP. We now provide conditions for when the scheme given in Lemma 3 is implementable, and hence optimal. For this scheme we have $\beta_{LL} = \eta Q_L + \frac{\delta}{1-\delta} [S - \pi + c]$ (since EA binds for this bonus), and inserting this and the other bonuses in EP the constraint takes the form

$$\frac{1}{\hat{q}_H + q_L} \left(\frac{c}{\Delta q} - \eta \Delta Q \right) \leq \frac{\delta}{1-\delta} [\Delta q \Delta Q - c]$$

Define $\delta_2 = \delta_2(\eta)$ as the minimal δ satisfying the inequality, i.e.

$$\frac{1 - \delta_2}{\delta_2} = \frac{[\Delta q \Delta Q - c]}{c - \eta \Delta q \Delta Q} (\hat{q}_H + q_L) \Delta q$$

From this we see that for $\delta \geq \delta_2$ the scheme given in the Lemma satisfies EP and hence is implementable. Note that δ_2 is decreasing in η . Hence, we have the following result.¹⁴

Proposition 4 *For $\eta \geq \eta_1$ and $\delta \geq \delta_2(\eta)$ the JPE wage scheme given by (15) is implementable and uniquely optimal. As the share of values (η) that the agents can hold-up ex post increases, the scheme approaches an IPE scheme.*

For given $\eta \geq \eta_1$ and for discount factors smaller than the critical factor δ_2 , the scheme (15) will no longer be implementable. For $\delta = \delta_2$ the dynamic enforceability constraint for the principal (EP) is binding for β_{HH} (and only for this bonus), while the agent's constraint EA is binding for the other bonuses. The least costly way for the principal to adapt to a lower δ (and hence a stricter EP) will then be to reduce β_{HH} , and by that reduce the difference $\beta_{HH} - \beta_{HL}$. Note also that a lower δ will also increase $\beta_{LH}, \beta_{LL}, \beta_{HL}$ when EA binds, see (15). Thus, a lower δ will force the principal to modify the scheme towards an IPE scheme. To sum up: The possibility for the agents to hold-up values forces the principal to offer a greater extent of individualized incentives at the expense of team incentives, even if the agents' tasks are perfect complements.

3.2 Peer pressure

A more striking demonstration of the JPE hold-up problem can be made in a setting with peer pressure. In order to highlight the effects of this feature, we return to the case of independent task technology, as modeled in Section 2. To model peer pressure in this framework, we assume that there are costs associated with lowering the peer's wage by realizing low output, i.e. that agents experience disutility from being the "weakest link". Such an event will occur with probability $(1 - q_H)q_H$ if $\beta_{HH} > \beta_{HL}$. We represent this disutility by $d = \max \{\nu(\beta_{HH} - \beta_{HL}), 0\}$, where ν is a cost parameter.

¹⁴Since the scheme is JPE, it does not yield uniqueness in the game played by the agents. Indeed, we have here $\pi(H, H, \beta) - c = \pi(L, H, \beta) = \pi(L, L, \beta)$, so efforts HH and LL are both equilibria, and they have equal payoffs. The agents thus have nothing to gain from playing the low effort equilibrium.

This assumption is in some sense in the spirit of Kandell and Lazear (1992). They distinguish between internal peer pressure, or guilt, when effort is unobservable among the agents, and external pressure, or shame, when effort is observable. In our model, effort is unobservable, so our assumption can be interpreted as guilt. However, output is observable, so the weakest link effect can also be interpreted as shame. A point here is that our assumption is not directly related to the disutility from low effort. It is output that matters. Low effort gives no disutility if it leads to high output (which it does with probability q_L .) And high effort may induce disutility if it leads to low output. The shame interpretation is therefore most appropriate.

Let D denote the expected disutility associated with being the weakest link:

$$D = (1 - q_H)q_H d = (1 - q_H)q_H \max \{\nu(\beta_{HH} - \beta_{HL}), 0\}$$

In a high effort equilibrium, each agent's expected utility is now

$$\begin{aligned} \pi - D - c &= q_H [q_H \beta_{HH} + (1 - q_H) \beta_{HL}] \\ &\quad + (1 - q_H) [q_H (\beta_{LH} - \max \{\nu(\beta_{HH} - \beta_{HL}), 0\}) + (1 - q_H) \beta_{LL}] - c \end{aligned}$$

This yields an IC constraint as follows

$$q_H \beta_{HH} + (1 - q_H) \beta_{HL} - q_H (\beta_{LH} - \max \{\nu(\beta_{HH} - \beta_{HL}), 0\}) - (1 - q_H) \beta_{LL} \geq \frac{c}{\Delta q} \quad (IC_d)$$

From this constraint and the definition of π we have

$$\begin{aligned} \pi &= q_H [q_H \beta_{HH} + (1 - q_H) \beta_{HL}] + (1 - q_H) [q_H \beta_{LH} + (1 - q_H) \beta_{LL}] \\ &\geq q_H \left[\frac{c}{\Delta q} + q_H (\beta_{LH} - \max \{\nu(\beta_{HH} - \beta_{HL}), 0\}) + (1 - q_H) \beta_{LL} \right] \\ &\quad + (1 - q_H) [q_H \beta_{LH} + (1 - q_H) \beta_{LL}] \end{aligned}$$

Hence

$$\pi \geq q_H \frac{c}{\Delta q} - q_H^2 \max \{\nu(\beta_{HH} - \beta_{HL}), 0\} + q_H \beta_{LH} + (1 - q_H) \beta_{LL} \quad (16)$$

We now see that if $\nu > 0$, it is uniquely optimal to set $\beta_{HL} = \beta_{LH} = \beta_{LL} = 0$, and (solving from IC_d) $\beta_{HH} = \frac{c}{q_H \Delta q (1 + \nu)}$. Hence, we have:

Proposition 5 *If output is verifiable, and there exists peer pressure ($\nu > 0$), there is a unique optimal wage scheme, namely the JPE scheme $\beta = (\beta_{HH}, 0, 0, 0)$ where $\beta_{HH} = \frac{c}{q_H \Delta q (1 + \nu)}$. The associated minimal wage cost is $\pi_m = q_H \frac{c}{\Delta q \nu + 1}$.*

We see that the wage cost is now lower than in the case where $\nu = 0$, i.e. $q_H \frac{c}{\Delta q} \frac{1}{\nu+1} < q_H \frac{c}{\Delta q}$ for $\nu > 0$ (see appendix on low effort equilibria). Hence, by offering incentives based on JPE, the principal can exploit the disutility effect of being the weakest link.

We will now demonstrate that when output is non-verifiable, the optimal scheme is not only a less stark JPE scheme. In fact any JPE scheme is sub-optimal once the relational contract constraints bind.

The dynamic enforceability constraint EA for the agents here takes the form

$$\min \{ \beta_{HH} - \eta Q_H, \beta_{HL} - \eta Q_H, \beta_{LH} - d - \eta Q_L, \beta_{LL} - \eta Q_L \} \geq \frac{\delta}{1-\delta} [S - \pi + D + c]$$

Using (16), which follows from the present IC-constraint, and EA for bonuses β_{LH} and β_{LL} , we get:

$$\begin{aligned} \pi &\geq q_H \frac{c}{\Delta q} - q_H^2 d + \left(\eta Q_L + \frac{\delta}{1-\delta} [S - \pi + D + c] + q_H d \right) \\ &= q_H \frac{c}{\Delta q} + \eta Q_L + \frac{\delta}{1-\delta} [S - (\pi - D) + c] + D \end{aligned}$$

Collecting terms involving $\pi - D$ and substituting for S we then obtain

$$\pi \geq q_H \frac{c}{\Delta q} + \eta Q_L - \delta \left[\frac{c}{\Delta q} - \eta \Delta Q \right] q_L + D$$

We see that to minimize π , the principal will want to set D as small as possible i.e. make $d = \max \{ \nu(\beta_{HH} - \beta_{HL}), 0 \}$ as small as possible. This means setting $\beta_{HH} - \beta_{HL} = 0$, provided this is feasible by EP. It follows that the IPE wage scheme together with the feasible RPE schemes on IC_d are optimal once the enforceability condition EA binds.

We see that for $\eta \geq \eta_0$ we have $\eta Q_L - \delta \left[\frac{c}{\Delta q} - \eta \Delta Q \right] q_L > 0$ for all $\delta \leq 1$, and so EA will indeed bind at outcomes LL and LH. Provided $\beta_{HH} - \beta_{HL} = 0$ is feasible (EP is satisfied), then EA' and IC' will hold. EP will be satisfied for this solution if EP' holds for $\beta_{HH} = \beta_{HL}$, which is the case if $2(\beta_{HH} - \beta_{LH} - \eta \Delta Q) \leq \frac{2\delta}{1-\delta} [\Delta q \Delta Q - c]$. From EA' and IC' we see that this holds if $\delta \geq \bar{\delta}$ given by

$$\frac{1 - \bar{\delta}}{\bar{\delta}} = \frac{[\Delta q \Delta Q - c]}{\frac{c}{\Delta q} - \eta \Delta Q}$$

For $\delta \geq \bar{\delta}$ an IPE wage scheme ($\beta_{HH} = \beta_{HL}$) is thus optimal.¹⁵ We have the

¹⁵It can be shown that for sufficiently low discount factors the "commitment advantage" of RPE dominates the problem of peer-dependence. An RPE scheme $\beta_{HL} > \beta_{HH} > 0$ is thus uniquely optimal for sufficiently low discount factors. The commitment advantage of RPE is analyzed in Kvaløy and Olsen (2006).

following result:

Proposition 6 *When there is peer pressure ($\nu > 0$) and agent hold-up ($\eta \geq \eta_0$) we have: For $\delta \geq \bar{\delta}$ an IPE wage scheme (with $\beta_{HH} = \beta_{HL}$) satisfying (8), IC_a and EA' is feasible and optimal. The minimal wage cost is π_{\min} given in Lemma 2. Any wage scheme with $\beta_{HH} - \beta_{HL} > 0$ yields a strictly larger cost, thus any JPE scheme is strictly inferior to IPE (and feasible RPE schemes).*

The intuition for this result goes as follows: without EA binding, the principal can exploit peer pressure by offering a JPE scheme so that the agents exert effort in order to avoid the weakest link disutility effect. Once EA binds, the agents have an outside market as a threat point. In the outside market IPE rules, and there are no disutility effects. In order to implement JPE, the principal then has to compensate the agents for this effect. But then JPE becomes more expensive than IPE or RPE, where no such effects exist. In other words: once the outside market becomes sufficiently tempting the principal can no longer use JPE to exploit the effect of peer pressure, but has to compensate the agents for any disutility effects that team incentives provide.

4 Concluding remarks

In an interesting review of the history of employment relationships, Peter Cappelli (2000) argues that the last twenty years have seen a dramatic shift from traditional bureaucratic employment structures to "inside contracting systems (...) shaped by individualized incentives and pressures from outside labor markets." In this paper we have analyzed the consequence of this trend on firms' ability to design peer-dependent incentives, such as relative and group-based performance pay. We have shown that compensation tied to peer-performance can induce employee-hold-up and obstruct the implementation of relational incentive contracts.

The model presented may explain the extensive use of individual performance pay in human-capital-intensive industries. Tremblay and Chenevert (2004) and Appelbaum (1991) note that even if knowledge-based industries are characterized by teamwork, the challenge to retain the most critical resources increases the pertinence of rewarding individual performance. Our model supports this conjecture.

In addition, the model can contribute to explain why relative performance

evaluation is used less in CEO compensation than agency theory suggests.¹⁶ Even though our model has a multilateral feature, i.e. one principal contracting with two agents, what drives our result is the agents' temptations to renegotiate when not being paid according to absolute output. A CEO interpretation is therefore not unreasonable since they are in the position of holding up values ex post if not being paid a "fair share" of their value added.

There is a large literature discussing human capital and problems of expropriation in modern corporations. Recent papers include Kessler and Lulfesmann (2006) who show how the firm can balance incentive provision between general and firm specific investments in human capital in order to mitigate the hold-up problem; and Rajan and Zingales (2001) who argue that human-capital-intensive industries will develop flat organizations with distinctive technologies and cultures in order to avoid expropriation. We complement this literature by showing how indispensable human capital affects the firm's feasible incentive design.

Our model also complements the seminal paper by Holmström and Milgrom (1994). They show how asset ownership gives a firm the ability to restructure the incentives of those who join the firm (the employees). In particular, they show how a firm - by giving up control rights - loses the ability to balance incentives between various tasks. We show how the firm - by giving up control rights - loses the ability to exploit the advantages that lies in designing peer-dependent incentives.

Appendix

Appendix to Lemma 1

We here verify the statements made in the remark following the lemma. For any contract β we have (Che and Yoo, 2001)

$$\pi(H, H, \beta) + \pi(L, L, \beta) - \pi(H, L, \beta) - \pi(L, H, \beta) = (q_H - q_L)^2 (\beta_{HH} - \beta_{HL})$$

When IC binds ($\pi(H, H, \beta) - c = \pi(L, H, \beta)$) we thus have

$$\pi(L, L, \beta) - (\pi(H, L, \beta) - c) = (q_H - q_L)^2 (\beta_{HH} - \beta_{HL})$$

This is non-negative for RPE or IPE contracts, hence efforts HH is then a unique equilibrium for the given contract. The expression is however negative for JPE, hence efforts LL is then another equilibrium.

Next compare equilibrium payoffs. Note that for $\beta_{LH} = \beta_{LL}$ we have

$$\pi(L, L, \beta) = q_L [q_L \beta_{HH} + (1 - q_L) \beta_{HL}] + (1 - q_L) \beta_{LL}$$

¹⁶See Murphy (1999) who states that 'the paucity of RPE in options and other components of executive compensation remains a puzzle worth understanding'. See also Aggarwal and Samwick (1999).

$$\pi(L, H, \boldsymbol{\beta}) = q_L [q_H \beta_{HH} + (1 - q_H) \beta_{HL}] + (1 - q_L) \beta_{LL}$$

so

$$\pi(L, L, \boldsymbol{\beta}) - \pi(L, H, \boldsymbol{\beta}) = -q_L \Delta q (\beta_{HH} - \beta_{HL})$$

Hence for a JPE contract with IC binding we have

$$\pi(L, L, \boldsymbol{\beta}) < \pi(L, H, \boldsymbol{\beta}) = \pi(H, H, \boldsymbol{\beta}) - c$$

Thus the HH equilibrium yields a higher payoff than the LL equilibrium.

Proof of Proposition 1

It remains to prove statement (ii). By definition of $\hat{\delta}$ no wage scheme can satisfy IC and EP' for $\delta < \hat{\delta}$. The statement then follows when we show that EP' is a necessary condition for implementability. To prove this, first note that EA implies

$$\beta_{Lj} - \eta Q_L \geq \frac{\delta}{1-\delta} [S - \pi + c], \quad j = H, L.$$

Condition EP implies

$$2(\beta_{HH} - \beta_{LH} - \eta \Delta Q) + 2(\beta_{LH} - \eta Q_L) = 2(\beta_{HH} - \eta Q_H) \leq \frac{2\delta}{1-\delta} [\Delta q \Delta Q - \pi + S]$$

and

$$\begin{aligned} (\beta_{HL} - \beta_{LL} - \eta \Delta Q) + (\beta_{LH} - \eta Q_L) + (\beta_{LL} - \eta Q_L) \\ = (\beta_{HL} + \beta_{LH} - \eta Q_H - \eta Q_L) \leq \frac{2\delta}{1-\delta} [\Delta q \Delta Q - \pi + S] \end{aligned}$$

Using these three inequalities we see that EP' follows. This completes the proof.

Verification of (10 - 11).

We verify here that (10 - 11) hold for the schemes stated in Proposition 1 when $\delta \geq \hat{\delta}$. We have

$$\begin{aligned} \pi - S &= \left(q_H \frac{c}{\Delta q} + \eta Q_L - \delta \left(\frac{c}{\Delta q} - \eta \Delta Q \right) q_L \right) - \eta (Q_L + \Delta Q q_L) \\ &= q_L \frac{c}{\Delta q} + c - \delta \left(\frac{c}{\Delta q} - \eta \Delta Q \right) q_L - \eta \Delta Q q_L \\ &= (1 - \delta) \left(\frac{c}{\Delta q} - \eta \Delta Q \right) q_L + c \end{aligned}$$

This shows that $\pi - S > c$, hence (10) holds. We further have

$$\begin{aligned} \pi - S - c &< (1 - \hat{\delta}) \left(\frac{c}{\Delta q} - \eta \Delta Q \right) q_L \\ &= \hat{\delta} \frac{[\Delta q \Delta Q - c]}{c - \eta \Delta Q \Delta q} \Delta q (2 - q_H) \left(\frac{c}{\Delta q} - \eta \Delta Q \right) q_L \\ &= \hat{\delta} [\Delta q \Delta Q - c] (2 - q_H) q_L < [\Delta q \Delta Q - c] \end{aligned}$$

where the last inequality follows from $\hat{\delta} < 1$ and $(2 - q_H) q_L < (2 - q_H) q_H < 1$.

Hence we see that (11) holds.

Verification of (13 - 14).

Substituting from β_{HH} from (IC_t) in $\pi(H, H, \boldsymbol{\beta})$ yields

$$\begin{aligned} \pi &\geq \frac{\hat{q}_H^2}{\hat{q}_H + q_L} \left(\frac{c}{\Delta q} - [1 - \hat{q}_H - q_L] (\beta_{HL} + \beta_{LH}) + [2 - \hat{q}_H - q_L] \beta_{LL} \right) \\ &\quad + \hat{q}_H (1 - \hat{q}_H) (\beta_{HL} + \beta_{LH}) + (1 - \hat{q}_H)^2 \beta_{LL} \end{aligned}$$

Hence

$$\begin{aligned}
\pi &\geq \frac{\hat{q}_H^2}{\hat{q}_H + q_L} \frac{c}{\Delta q} + \hat{q}_H^2 \left(\frac{1 - \hat{q}_H}{\hat{q}_H} - \frac{1 - \hat{q}_H - q_L}{\hat{q}_H + q_L} \right) (\beta_{HL} + \beta_{LH}) \\
&\quad + \hat{q}_H^2 \left(\frac{(1 - \hat{q}_H)^2}{\hat{q}_H^2} + \frac{2 - \hat{q}_H - q_L}{\hat{q}_H + q_L} \right) \beta_{LL} \\
&= \frac{\hat{q}_H^2}{\hat{q}_H^2 - q_L^2} c + \frac{\hat{q}_H q_L}{\hat{q}_H + q_L} (\beta_{HL} + \beta_{LH}) + \left(1 - \frac{2\hat{q}_H q_L}{\hat{q}_H + q_L} \right) \beta_{LL}
\end{aligned}$$

This verifies (13).

Then, using EA for $\beta_{HL}, \beta_{LH}, \beta_{LL}$ in (13) yields

$$\pi \geq \frac{\hat{q}_H^2}{\hat{q}_H^2 - q_L^2} c + \frac{p}{2} \eta \Delta Q + \eta Q_L + \frac{\delta}{1 - \delta} [S - \pi + c]$$

Collecting terms involving π and substituting for $S = \eta(Q_L + q_L \Delta Q)$ we get

$$\begin{aligned}
\pi &\geq (1 - \delta) \left(\frac{\hat{q}_H^2}{\hat{q}_H^2 - q_L^2} c + \frac{p}{2} \eta \Delta Q + \eta Q_L \right) + \delta [S + c] \\
&= \frac{\hat{q}_H^2}{\hat{q}_H^2 - q_L^2} c + \frac{p}{2} \eta \Delta Q + \eta Q_L - \delta \left[\frac{q_L^2}{\hat{q}_H^2 - q_L^2} c - \eta \left(q_L - \frac{p}{2} \right) \Delta Q \right]
\end{aligned}$$

We have $q_L - \frac{p}{2} = q_L - \frac{\hat{q}_H q_L}{\hat{q}_H + q_L} = \frac{q_L^2}{\hat{q}_H + q_L}$. This verifies (14).

Proof of Lemma 3

Note first that $\eta_1 \Delta q \Delta Q < c$ for $Q_L > 0$, hence (6) is satisfied. The derivation of (14) shows that for $\eta \geq \eta_1$ the minimal wage cost is given by $\pi_m(\delta)$, that this cost exceeds the minimal cost for verifiable output, and that the minimum is attained when IC binds, and when EA binds for $\beta_{HL}, \beta_{LH}, \beta_{LL}$.

To verify the expression for β_{LL} note that (13) may be written as $\pi \geq \frac{\hat{q}_H^2}{\hat{q}_H^2 - q_L^2} c + \frac{p}{2} ((\beta_{HL} - \beta_{LL}) + (\beta_{LH} - \beta_{LL})) + \beta_{LL}$. When EA binds for $\beta_{HL}, \beta_{LH}, \beta_{LL}$ the RHS equals $\pi_m(\delta)$, and we thus have $\pi_m(\delta) = \frac{\hat{q}_H^2}{\hat{q}_H^2 - q_L^2} c + \frac{p}{2} \eta \Delta Q + \beta_{LL}$. This yields the stated expression for β_{LL} . Next, substituting for $\beta_{LH} = \beta_{LL} = \beta_{HL} - \eta \Delta Q$ in (IC_t) and solving this for β_{HH} when the constraint binds then yields the stated expression for β_{HH} . To see this, note that the substitution yields

$$[\hat{q}_H + q_L] \beta_{HH} + [1 - \hat{q}_H - q_L] (2\beta_{HL} - \eta \Delta Q) - [2 - \hat{q}_H - q_L] (\beta_{HL} - \eta \Delta Q) = \frac{c}{\Delta q}$$

Solving this for β_{HH} yields the stated expression.

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