

Relative Performance Evaluation, Agent Hold-Up and Firm Organization*

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Abstract

We analyze a situation where common noise makes compensation based on relative performance evaluation (RPE) desirable, but where the agents' ability to hold-up values ex post obstruct the implementation of optimal RPE schemes. The principal can take actions to constrain the agents' hold-up power by limiting their outside options and by protecting property rights, but once these actions are costly, a trade-off between incentive provision and agent control appears. The model contributes to the theory of the firm. It indicates why firms, not agents, own assets, and why peer-dependent incentive systems are more common within than between firms.

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1 Introduction

Assume you work at a University that bases some of your wage on the department's performance. One day you get accepted in a top ranked journal. The department chair celebrates (and so do you), but you are a bit worried about this year's bonus because your colleagues haven't been too productive lately. What do you do? Well, no one is able to take your publication away from you, and since a number of Universities are willing to pay for your achievements, you go back to the department chair, show her your job offers, and renegotiate the wage.¹ The department chair then has a dilemma. By agreeing to renegotiate the bonus, she obstructs the whole idea of paying on the basis of group performance.

Next year, your University decides to implement bonuses based on relative performance. Each department is asked to rank their researchers' performance and then pay bonuses according to this ranking. Again you achieve a nice publication. The problem this year, however, is that so do also your colleagues. In fact they do even better than you, and your bonus becomes rather poor. What do you do? Again you take your publication with you, apply for job elsewhere and come back to renegotiate the wage. The University evaluates its incentive system and concludes: It has to base bonuses on individual performance.

Your university collaborates with a high-tech company who shares some of the same problems. The engineers run away or renegotiate wages once they have developed a promising concept. The trouble is that both group incentives and tournaments are crucial for promoting cooperation and competition among the engineers. So instead of changing to individually based incentives, the company chooses the strategy of asset control. By carefully developing a system of patent protection, and by assuring that their engineers do not get access to a larger share of strategic assets than necessary, they are able to implement peer-dependent incentives without running the risk of opportunism and expropriation.

In his paper "The firm as a subeconomy" Holmström (1999) asks: why do modern

¹In some countries, the universities' funding partly depends on publications. This makes researchers with publications that are forthcoming especially attractive.

firms own essentially all of the productive assets that it employs? And he answers: when a firm owns the critical assets involved in production, it has the ability to restructure the incentives of those who join the firm (the employees). In particular, by owning assets the firm can avoid problems of multitasking and rent seeking. (The ideas from Holmström’s 1999-paper are based on Holmström and Milgrom, 1991 and 1994.) We further develop this idea by making the following point: if a firm does not control its assets, or more generally if its workers are able to hold-up values ex post production, then incentive contracts based on peer-dependence are costly to implement. While Holmström and Milgrom 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 lie in designing peer-dependent incentives. An implication from our analysis is that the firm will control its assets if there exists conditions that make peer-dependent performance evaluation desirable.² In particular, we show that if there exists common noise that makes relative performance evaluation optimal, then the firm will be more reluctant to allow its employees to possess considerable hold-up power.

Our approach involves assuming that it is costly for the firm to control its employees’ hold-up power, where this power is a function of bargaining power and outside

²The literature has pointed on 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).

options. These costs of constraining the workers' hold-up power can follow from patenting that seeks to protect (intellectual) property rights, or from designing specific non-competing clauses in the employment contract.³ The firm can also reduce the workers' hold-up power through allocation of asset ownership (as in the property rights approach, starting with Grossman and Hart, 1986), or through access control (as in Rajan and Zingales, 1998). The workers' hold-up power will also depend on the specificity of the their value-added. The more firm specific human capital the workers possess - or the more narrow their skill sets are - the lower is the alternative value of the workers' production, relative to firm specific value. But even if the alternative value is zero, the workers can still hold-up values if they possess essential human capital that makes them indispensable for ex post value extraction. The firm can thus reduce the workers' hold-up power through job design, such as job rotation (see e.g. Halonen-Akatwijuka, 2006), making them ex post dispensable.

Assuming, then, that the firm can choose how much hold-up power it will admit its agents to possess, we investigate the trade-off between incentive provision and the costs of controlling the agents' hold-up power. This idea is related to the literature on human capital and the problems of expropriation (see e.g. Liebskind, 1996; Rebitzer and Taylor, 2001; and Rajan and Zingales, 2001). The focus in this literature is on how organizational design and incentive structure can affect the firm's ability to protect strategic assets. While the costs of trying to avoid expropriation is at the heart of this literature and is thus endogenous, the costs of losing control over strategic assets is exogenous. We endogenize the costs of losing control by showing that these costs vary with the gain from being able to implement advantageous incentive systems, in particular systems involving relative performance evaluation.

In the theory of the firm literature, the boundaries of the firm are often defined by the total hold-up power of the seller (see e.g. Grossman and Hart, 1986, and Baker, Gibbons and Murphy, 2002), where the hold-up power typically is zero, or small, for employees and high for independent suppliers/contractors. We consider a continuous index of hold-up power instead of a discrete integration vs non-integration

³See Levin and Tadelis (2005) for an interesting discussion of non-compete clauses in partnerships.

variable, and endogenously determine the level of this power index. A higher degree of hold-up power can then be interpreted as a move from more integrated to less integrated transactions. A corollary from our analysis is then that integrated transactions exhibit more common noise and peer-dependent incentive systems, while non-integrated transactions exhibit less noise and independent performance pay. Interestingly, we also find that the marginal cost of higher agent-hold-up increases with the parties' discount factor, δ , i.e. their valuation of future trade. If we interpret the discount factor as a measure of the dependency, or trust level, between the transacting parties, we may take $\delta = 0$ to represent spot transactions, and $\delta = 1$ to represent fully dependent high-trust relationships. A result from our model is then that spot transactions are more likely to be organized in markets, while long-term relationships are more likely to be organized within firms. This appears to be a highly plausible prediction.

Our results rest on a premise that the quality of the workers' output is non-verifiable, and that the incentive contracts therefore are incomplete. As is well known, the problem of incomplete contracting can be mitigated by repeated interaction. Through repeated transactions the parties can make it costly for each other to breach the contract, by letting breach ruin future trade. The parties can thus commit to engage in so-called self-enforcing relational contracting.⁴ In Kvaløy and Olsen (2006a, 2006b), we investigate the scope for implementing team incentives in relational contracts. The present paper complements and extends Kvaløy and Olsen (2006b) in two respects. First, we introduce common noise - making relative performance evaluation optimal. Second, and most importantly, we endogenize the agents' hold-up power, and deduce optimal agent-hold-up from the viewpoint of the principal.

The papers fill a gap: In the vast literature on “multiagent moral hazard” (which deals with optimal provision of incentives to several workers), it is (implicitly) assumed that residual control rights are exclusively in the hands of the firm (influential papers include Lazear and Rosen, 1981, and Holmström, 1982). And in the litera-

⁴There is a growing literature on relational contracting, see in particular recent influential papers by Baker, Gibbons and Murphy (2002) and Levin (2003).

ture dealing with optimal allocation of control rights, the multiagent moral hazard problem is not considered (starting with Grossman and Hart, 1986; and Hart and More, 1990⁵, who analyze static relationships, and more recently Halonen, 2002; and Baker, Gibbons and Murphy, 2002, who analyze repeated bilateral relationships). Our contribution is thus to consider the effect of workers possessing residual control rights when the firm faces a multiagent moral hazard problem.

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.⁶

The agents' outputs depend on efforts and noise. We follow Che and Yoo (2001), assuming that a favorable shock occurs with probability $\sigma \in (0, 1)$, in which both agents produce high values for the principal. If the shock is unfavorable, the probability for agent i of realizing Q_H is q_H if the agent's effort is high and q_L if the agent's effort is low, where $1 > q_H > q_L \geq 0$. As one may expect, the common noise factor makes relative performance evaluation desirable. This aspect complements and extends the model analyzed in Kvaløy and Olsen (2006b).

It is assumed that all parties are risk neutral, but that the agents are subject to limited liability: the principal cannot impose negative wages.⁷ Ex ante outside options are normalized to zero. The participation constraint then holds trivially by

⁵Although 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.

⁶Whether 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.

⁷Limited liability may arise from liquidity constraints or from laws that prohibit firms from extracting payments from workers.

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_k , ($k = H, L$).

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

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

For each agent, a wage scheme exhibits joint performance evaluation if $(\beta_{HH}, \beta_{LH}) > (\beta_{HL}, \beta_{LL})$ ⁸. (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.

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

$$(1 - \sigma) \Delta q \Delta Q \geq c \quad (2)$$

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

⁸The inequality means weak inequality of each component and strict inequality for at least one component.

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

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

Now, by IC and the definition (1) of the wage cost $\pi(k, l, \beta)$, we have, for $\pi = \pi(H, H, \beta)$:

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

From this and limited liability ($\beta_{LH} \geq 0$) we see that the optimal incentive contract is a stark RPE scheme:

Lemma 1 *With common noise $\sigma > 0$ there is a unique optimal static wage scheme $\beta^s = (0, \beta_{HL}, 0, 0)$, where $\beta_{HL} = \frac{c}{(1 - \sigma) \Delta q (1 - q_H)}$. The minimal wage cost is $\pi = q_H \frac{c}{\Delta q}$.*

Remark. As noted above, a contract will induce high effort from both agents as a unique equilibrium in the agents' game if addition to IC it satisfies $\pi(H, L, \beta) - c \geq$

$\pi(L, L, \beta)$. It can be shown that for any contract that satisfies IC with equality, this condition will hold if the contract is RPE or IPE.

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 multilateral 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 all previous periods. The agents honor the contract only if the principal honored the contract with both agents in all previous periods. 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 may call a spot contract. The spot price is denoted ηQ_k . If values accrue directly to the principal, then $\eta = 0$. But if the agent is able to hold-up values ex-post, 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. If we assume Nash bargaining between principal and agents, each agent will then receive θQ_k plus a share γ from the surplus from trade i.e. $\theta Q_i + \gamma(Q_k - \theta Q_k) = \eta Q_k$ where $\eta = \gamma + \theta(1 - \gamma)$. The agents’ total hold-up power, η , is then a positive function of bargaining power and outside options.

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

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

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

$$\eta(1 - \sigma)\Delta q\Delta Q < c \tag{6}$$

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

$$\eta < \frac{c}{(1 - \sigma)\Delta q\Delta Q} \leq 1.$$

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

$$\begin{aligned} & -\beta_{kl} - \beta_{lk} + \frac{2\delta}{1 - \delta} [Q_L + (\sigma + (1 - \sigma)q_H)\Delta Q - \pi] \\ \geq & -\eta(Q_k + Q_l) + \frac{2\delta}{1 - \delta} [Q_L + (\sigma + (1 - \sigma)q_L)\Delta Q - S], \quad k, l \in \{H, L\} \end{aligned}$$

where $S = \eta(Q_L + (\sigma + (1 - \sigma)q_L)\Delta Q)$ 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 $\beta_{kl} + \beta_{lk} - \eta(Q_k + Q_l)$ is maximal. We can thus write the condition as

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

Agent i will honor the contract if

$$\beta_{kl} + \frac{\delta}{1-\delta}(\pi - c) \geq \eta Q_k + \frac{\delta}{1-\delta}S, \quad k, l \in \{H, L\}$$

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 $\beta_{kl} - \eta Q_k$ is minimal. We can thus write the condition as

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

2.2.2 Optimal relational contract

To minimize expected wage costs, the principal will solve

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

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

$$\begin{aligned} \pi \geq \sigma \left(\eta Q_H + \frac{\delta}{1-\delta} [S - \pi + c] \right) \\ + q_H \frac{c}{\Delta q} + (1-\sigma) \left(\eta Q_L + \frac{\delta}{1-\delta} [S - \pi + c] \right) \end{aligned}$$

Collecting terms involving π and substituting for the spot price $S = \sigma\eta Q_H + (1 - \sigma)\eta(Q_L + q_L\Delta Q)$, this relation yields a lower bound for the wage cost. By an argument similar to that in Kvaløy and Olsen (2006b) the following result can then be established.

Lemma 2 *In relational contracting we have:*

(i) *The wage cost π is bounded from below by π_{\min} given by*

$$\pi_{\min} = q_H \frac{c}{\Delta q} + \max\{0, \eta Q_L + \sigma\eta\Delta Q - \delta q_L(\frac{c}{\Delta q} - (1 - \sigma)\eta\Delta Q)\} \quad (8)$$

(ii) *There exists $\eta_0 < \frac{c}{(1-\sigma)\Delta q\Delta Q}$ and $\tilde{\delta} < 1$ such that for $\eta > \eta_0$ the lower bound π_{\min} exceeds the cost for the verifiable case ($\pi_{\min} > q_H \frac{c}{\Delta q}$), and can be attained if $\delta > \tilde{\delta}$.*

(iii) *For $\eta > \eta_0$ the cost π_{\min} is decreasing in the common noise parameter σ .*

From the previous section we know that IC and limited liability implies $\pi \geq q_H \frac{c}{\Delta q}$. The implementability conditions (EA) for the agents lead to the additional term in the expression for π_{\min} . This term is increasing in η and decreasing in δ , reflecting the fact that the EA conditions are more demanding when the agents have more hold-up power (larger η) and less demanding for larger δ . The term is positive for all $\delta \leq 1$ when $\eta > \eta_0 = \frac{q_L}{Q_L + (\sigma + q_L(1-\sigma))\Delta Q} \frac{c}{\Delta q}$, implying that π_{\min} then strictly exceeds the wage cost for the verifiable case. In the following we will assume that the hold-up problem is serious in the sense that this condition ($\eta > \eta_0$) holds.¹⁰

The cost π_{\min} is attained when IC binds and EA is binding for the bonuses β_{HH}, β_{LH} and β_{LL} . For the lower bound π_{\min} to be attainable the associated bonuses must also satisfy the implementability conditions EP for the principal. The latter are more easily satisfied, the larger is δ . Statement (ii) in the lemma makes the point that the relevant bonuses can be implemented, and hence the lower bound π_{\min} can be attained, when δ exceeds some critical factor $\tilde{\delta} < 1$.¹¹

¹⁰Note that $\eta = \eta_0$ satisfies condition (6) with strict inequality when $Q_L > 0$, hence there is a non-empty set of η 's satisfying $\eta > \eta_0$ and (6).

¹¹It can be verified that the critical factor $\tilde{\delta}$ is given by $\frac{1-\tilde{\delta}}{\tilde{\delta}} = \frac{2[(1-\sigma)\Delta q\Delta Q - c](1-q_H)}{(c - (1-\sigma)\eta_0\Delta q\Delta Q)}(1-\sigma)\Delta q$.

Note that, contrary to the verifiable case, the minimal wage cost π_{\min} increases with more common noise ($\frac{\partial \pi_{\min}}{\partial \sigma} = \eta \Delta Q (1 - \delta q_L) > 0$). This is so because the principal is prevented from using the stark RPE scheme. The intuition behind the result is simple: With RPE, an agent is not paid well if his peer performs better. This peer-dependence triggers breach of the relational contract since an agent who is paid a low bonus after realizing a high output, has incentives to hold-up his output and renegotiate payments. Hence, when contracts are incomplete and the agents possess hold-up power, it is more costly to exploit common noise when designing incentives.¹²

3 Endogenous hold-up power

If the principal/firm bears no cost of controlling the agents' hold-up power, then the firm's wage costs are minimized if η is minimized, (subject to the constraints that ensure high-effort equilibria). But assume now that there are costs $C(\eta)$ associated with reducing the agents' hold-up power, where $C'(\eta) < 0$. Recall that we assumed an alternative market for the agents' output, where they independently could realize values θQ_k , $\theta \in (0, 1)$ ex post. Assuming Nash bargaining between principal and agents, each agent would then receive θQ_k plus a share γ from the surplus from trade i.e. $\theta Q_k + \gamma(Q_k - \theta Q_k) = \eta Q_k$ where $\eta = \gamma + \theta(1 - \gamma)$. The firm can then reduce η by reducing θ and/or reducing γ .

The firm's effort to avoid ex post expropriation can in our model be seen as an effort to reduce θ . This can be achieved by investments in patent protection that seek to protect intellectual property rights. It can also be achieved through non-compete clauses in the employment contract; where a verifiable non-compete clause in principle can attain $\theta = 0$. The firm can also reduce θ through allocation of asset ownership. The fewer assets owned by the agents, the lower is θ . The parameter θ

¹²The idea that outside opportunities affect incentives is also promoted by Oyer (2004), who show that firms may find it profitable to pay wages that are correlated with outside options. As opposed to Oyer we look at variations in the ex post outside opportunities, not the ex ante participation constraint. Moreover, Oyer does not consider the multiagent moral hazard problem.

also depends on the specificity of the agents' value-added. The more firm specific human capital the agents' possess - or the more narrow their respective skill sets are - the lower is θ . But even if $\theta = 0$, the agents can still achieve a share $\eta = \gamma$ ex post. This share γ from the *surplus* from trade is determined by bargaining power, and will typically increase with the indispensability of the agents: If agents possess essential human capital that makes them indispensable for ex post value extraction, then γ is high. The firm can thus reduce γ by making the agents ex post dispensable. This can be achieved through job design, such as job rotation. The less specialized the agents are, the lower is γ . But as noted, a high degree of specialization can reduce outside options and thus reduce θ , so the overall effect of specialization may be ambiguous. Specialization may increase γ , but decrease θ .

The firm/principal's objective is now to minimize $\pi(\eta)+C(\eta)$. Note that since π is linear in η , the problem has a corner solution if $C''(\eta) \leq 0$, implying that we will then see only "extreme" organizational solutions. Let $\underline{\eta}$ and $\bar{\eta}$ denote, respectively, the minimal and the maximal feasible hold-up power for the agents. The firm will then choose $\eta = \underline{\eta}$ if $\pi(\underline{\eta})+C(\underline{\eta}) < \pi(\bar{\eta})+C(\bar{\eta})$, and $\eta = \bar{\eta}$ if $\pi(\underline{\eta})+C(\underline{\eta}) > \pi(\bar{\eta})+C(\bar{\eta})$. This implies that a small parameter change can give a significant change in organizational design.

Whether $C(\eta)$ is concave or convex is difficult to assess. But following the standard assumptions regarding cost functions, we may assume that the function is convex for a given agent: The costs of ensuring some protection are relatively low, but the marginal costs of avoiding any hold-up power are likely to be significant. If $C''(\eta) > 0$ there is an interior solution satisfying¹³

$$\pi'_{\min}(\eta) = Q_L + \sigma\Delta Q + \delta q_L(1 - \sigma)\Delta Q = -C'(\eta) \quad (9)$$

We now observe that the higher is $\pi'_{\min}(\eta)$, the lower η the firm will choose. Observe that (for $\delta > \tilde{\delta}$) we have

$$\frac{\partial}{\partial \sigma} \pi'_{\min}(\eta) = \Delta Q(1 - \delta q_L) > 0$$

¹³We assume here that (9) has a solution in the range of admissible η 's.

Hence, the more common noise, the higher are absolute wage costs (π_{\min}), and the higher are the marginal wage costs ($\pi'_{\min}(\eta)$) associated with admitting hold-up power to the agents. The more common noise, the lower is thus the optimal η ; the firm wishes to take a stronger control over the agents' assets if the agents are exposed to more common noise. Note that there are two effects that makes a higher η more costly when common noise is introduced. The first, least interesting effect, is through the higher expected spot price that the agents can achieve when our specific specification of common noise is introduced. This higher spot price must be matched through higher fixed payments $\beta_{HL} = \beta_{LL}$.

The more interesting effect is the cost of losing the ability to implement the optimal degree of peer-dependence, namely, the starkest RPE scheme. In contrast, when there is no common noise, there are no costs of not being able to implement peer-dependent incentives. We can summarize this discussion in the following proposition.

Proposition 1 *For $\delta \geq \tilde{\delta}$ we have: (i) The higher is the common noise factor, the more the firm loses from its inability to implement the optimal degree of RPE in the wage scheme. (ii) The higher is the common noise factor, the lower is the firm's optimal η , and hence the higher is the firm's optimal level of control over the relevant assets.*

We can also ask whether (and how) the agents' effort-productivity $\Delta q \Delta Q / c$ affects the firm's choice of η . We can write $\pi'_{\min}(\eta)$ as $Q_L + \sigma(Q_H - Q_L) + \delta q_L(1 - \sigma)(Q_H - Q_L)$. We then have:

$$\begin{aligned} \frac{\partial}{\partial Q_L} \pi'_{\min}(\eta) &= (1 - \sigma) - \delta q_L(1 - \sigma) > 0 \\ \frac{\partial}{\partial Q_H} \pi'_{\min}(\eta) &= \sigma + \delta q_L(1 - \sigma) > 0 \\ \frac{\partial}{\partial q_L} \pi'_{\min}(\eta) &= \delta(1 - \sigma)\Delta Q > 0 \end{aligned}$$

We see that the effect of higher $\Delta q \Delta Q$ on $\pi'_{\min}(\eta)$ depends on parameter values, since $\pi'_{\min}(\eta)$ increases in both Q_L , Q_H , and q_L , while it is not at all affected by q_H

and c . But note that $\frac{\partial}{\partial Q_H} \pi'_{\min}(\eta)$ increases in the noise factor σ , while $\frac{\partial}{\partial Q_L} \pi'_{\min}(\eta)$ and $\frac{\partial}{\partial q_L} \pi'_{\min}(\eta)$ decrease in σ . Hence, with more common noise present, it is more likely that a higher effort productivity, $\Delta q \Delta Q / c$, increases $\pi'_{\min}(\eta)$, and thus reduces the optimal η . The intuition is as follows: The value of providing incentives increases with effort productivity, and as we know, common noise makes incentives based on RPE optimal. Since a higher η reduces the feasibility of RPE, the optimal η decreases with effort productivity when common noise is significant. Thus we may state the following.

Proposition 2 *For $\delta \geq \tilde{\delta}$ we have: Higher effort productivity (higher $\Delta q \Delta Q / c$) may, depending on the parameters reduce, increase or leave unaffected the firm's optimal degree of asset control (η). The higher is the common noise factor, the more likely it is that higher effort productivity reduces η , and hence increases the firm's optimal level of asset control.*

Finally, there is a comparative static result regarding the discount factor δ that is worth commenting. Observe that the marginal wage cost of higher η increases with the discount factor:

$$\frac{\partial}{\partial \delta} \pi'_{\min}(\eta) = q_L(1 - \sigma) \Delta Q > 0 \quad (10)$$

The reason behind this is as follows. A higher δ reduces the firm's wage costs' ceteris par (see eq. (8)), since the agents' benefits from renegeing on the relational contract decrease with δ . However, the marginal wage reduction from higher δ decreases with η , since the benefit from renegeing on the relational contract increases with η .

We can interpret the discount factor as a measure of the dependency, or trust level, between the transacting parties (see e.g. Hart, 2001, on interpreting δ as trust; and James Jr., 2002, for a nice survey on the economic concept of trust). We may then take $\delta = 0$ to represent spot transactions, and $\delta = 1$ to represent fully dependent high-trust relationships. Interestingly, we can then state

Proposition 3 *For $\delta \geq \tilde{\delta}$ we have: The higher is the discount factor, the higher is the marginal wage cost of increasing η , and thus the lower is the firm's optimal η .*

The higher is δ , the higher is thus the firm's optimal level of control over the relevant assets.

It is natural to assume that the hold-up index η is higher in relationships between firms than within firms. In parts of the literature, the boundaries of the firm are implicitly defined by the hold-up power of the seller (see e.g. Grossman and Hart, 1986, and Baker, Gibbons and Murphy, 2002), i.e. the magnitude of η determines whether parties are integrated or non-integrated, where typically $\eta = 0$, or low, for employees and η is high for independent suppliers. A novelty in our model is the endogenous determination of a continuously varying η instead of a discrete η , but an increase in η can still be interpreted as a move from integrated transactions to non-integrated transactions. An implication of the last proposition is then that spot transactions are more likely to be non-integrated, while long-term relationships are more likely to be organized within firms.

Before we conclude, it should be noted that we do not discuss *Pareto optimal* hold-up power. In fact, this question is trivial here. The critical discount factor for implementing first best (high) effort decreases with the agents' hold-up power, simply because it is the agents that take on investments (effort). However, by constraining our attention to the range of parameters where first-best effort is implemented, we can ask how the firm optimally will determine the workers' hold-up power. In such, our approach is related to Holmström and Milgrom who also take a "firm perspective" by discussing how much asset ownership the firm should admit its agents to have. In their model, the firm optimally trades off the "incentive costs" (i.e. the lower-powered agent incentives) of controlling assets against the benefits of being able to balance incentives between tasks. In our model, the firm trades off the "protection costs" of controlling assets - or more generally controlling the agents' hold-up power, against the benefits of being able to exploit peer-dependence (relative performance evaluation) in its incentive design.

4 Concluding remarks

In this paper we argue that the firm will be more reluctant of giving hold-up power, such as asset ownership, to workers if there exist conditions that call for peer-dependent incentives.¹⁴ In particular, we show that if there exists common noise that makes relative performance evaluation optimal, then the firm will increase its efforts to reduce the workers' hold-up power.

The model has several empirical implications. One is that we will see less peer-dependent incentives in markets or industries where it is difficult or costly to limit the workers' outside options. Hence, we will see less peer-dependence in industries with well-developed job markets. For instance, the mid-career job market is relatively underdeveloped in Japan compared to the US, and interestingly there is a lesser degree of individual performance pay, and greater peer-dependence through job rotation, teamwork and so-called J-type tournaments in Japan than in the US. (In J-type tournaments aggregate bonus pools are fixed such that the workers' pay is affected by the marginal performance of their peers; see Kräkel, 2002, for an analysis of J-type tournaments, and Endo (1994) and Itoh (1991) for discussions of incentive pay and HRM-practice in Japanese firms.) Research indicating that individual performance pay is more common in human capital intensive industries (Long and Shields, 2005, Barth et al., 2006) also supports our model's predictions.¹⁵ The analysis can also explain why relative performance evaluation is used less in CEO compensation than standard agency theory suggests.¹⁶ Even though our model has a multilateral fea-

¹⁴Although we concentrate on relative performance evaluation rather than team incentives in this paper, the insight that hold-up limits the feasible degree of peer-dependent incentives also applies to team incentives.

¹⁵Although team-based incentives are quite common in high-skilled businesses such as law firms and software industries, several studies indicate a positive relationship between the intensity of human capital and the prevalence of individual performance pay. In addition to the referred studies by Long and Shields (2005) and Barth et al. (2006). Kato (2002) and Torrington (1993) indicate that workers with more education are particularly interested in receiving rewards tailored to individual performance, and 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.

¹⁶See Murphy (1999) who states that 'the paucity of RPE in options and other components of

ture, our results are driven by 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.

We also believe that the model contributes to the theory of the firm. A theory of the firm should explain some defining characteristics of the firm, such as (i) The firm owns critical assets (ii) The activities are correlated such that agents are exposed to some common noise. (iii) Contracts are long-term, to a larger extent within than between firms. (iv) Contracts are incomplete, to a larger extent within than between firms. Our model predicts that within firm transactions (low η) are typical when there is much common noise and when contracts are long-term (high δ). It also suggests why activities that keep η low are associated with firms rather than markets, e.g. why the ownership of assets are clustered in firms, and why between-firm transactions do not have the same sophistication as within firm transactions where job rotation and strategic job design are important.

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