WORKING PAPERS IN ECONOMICS

No. 01/04

BURKHARD HEHENKAMP AND ODDVAR KAARBØE

WHEN THE TALENTED SHOULD RECEIVE WEAKER INCENTIVES: PEER PRESSURE IN TEAMS

Department of Economics

UNIVERSITY OF BERGEN

When the Talented Should Receive Weaker Incentives: Peer Pressure in Teams

Burkhard Hehenkamp* and Oddvar Kaarbøe†

February 5, 2004

Abstract

We study optimal incentive contracts in teams which consist of two groups of agents differing in their productivity, and in situations where team members feel a social pressure to exert similar effort levels. We show that it is first-best optimal to induce the more productive agents to exert higher effort. We then characterize the equilibrium under agency. The general conclusion we obtain regarding economic incentives is that the principal always chooses to give the less productive agents the strongest incentives. That is, less productive agents are offered a salary scheme that is more responsive to the team output than it is the case for the more productive agents. Furthermore, we show that the principal is able to implement the unique first-best solution. In this solution less productive agents exert less effort, and all agents experience peer pressure.

*Department of Economics, University of Dortmund, D-44221 Dortmund, Germany. Email: b.hehenkamp@wiso.uni-dortmund.de. The paper was written during my research visit at the University of Bergen. I would very much like to thank the people at the Department of Economics for creating such a warm and inspiring research atmosphere. I also thank Ruhrgas and the Programme for Health Economics in Bergen for making this research visit possible.

†Corresponding author. Programme for Health Economics (HEB), Department of Economics, University of Bergen. Fosswinckelsg. 6, N-5007 Bergen. Norway. Email: oddvar.kaarboe@econ.uib.no URL http://www.econ.uib.no/stab/oddvar.html

1 Introduction

In many organizations, individuals feel a social pressure to exert similar effort levels. In such organizations intra-group effort comparison between its members may lead to effort norms. This means that informal interactions among the group members make it costly for individuals to perform an effort level that differs from the effort norm established in their work group, (Encinosa, Gaynor, and Rebitzer, 1997). Effort norms can be sustained by feelings of guilt or shame when not carrying one's share of the group's work (Kandel and Lazer, 1992). Alternatively, effort norms can result from the praise a group member receives from working harder than others in the group.

Effort norms are studied empirically in Encinosa, Gaynor, and Rebitzer (1997). These authors find that intra-group effort comparisons among physicians matter in medical partnerships. The fact that peer pressure (or intra-group comparisons) affect individuals' choice of effort is also supported by experimental data. In a laboratory study, Falk, Fischbacker, and Gächter (2002) find that the same individual contributes more to a public good in a group with high average contributions then in a group with a low contribution level. Falk and Ichino (2003) show in a controlled field experiment that the behavior of subjects working in pairs is significantly different from behavior of subjects working alone.

While it might be the case that peer pressure can raise the effort levels in a group, and hence the group's production, peer pressure will typically also affect the employee's profits or utility negatively since workers have to be compensated for the potential negative utility effects that originate from peer pressure. A question that naturally arises is thus how peer effects affect individuals' behavior, and thereby the employee's profits. How can the employee affect individual workers' behavior by use of economic incentives when peer pressure effects are present? How do the optimal incentive contracts look like in the present of peer effects? These are the questions we attempt to answer in this paper.

To do so we put forward a simple principal-agent model of team production when peer effects are presents. In the model, individual output depends on the effort chosen by the individual and on his productivity (or talent). Team output equals the sum of all individuals' production. Individual production, and hence each individual's effort level, is unobserved by the employee (or the principal), but total team output can be observed and verified. Furthermore, we assume that the principal observes a signal of each individual agent's productivity (or talent), and that the principal is able to condition individual pay on this signal. Examples of such signals can be the individual's years of schooling, formal levels of training, his position etc.[1] In this way we are able to analyze a situation where the agents' productivities differ.

The following example illustrates the type of situations we have in mind. Consider a team consisting of a specialist physician and of an assistant physician working at a hospital department. Each physician's ability and choice of effort determines how many patients the department as a whole is able to treat within a certain time period. As in Encinosa, Gaynor, and Rebitzer (1997), let the informal interactions among the physicians make it costly for each physician to perform an effort level that differs from the effort norm that is endogenously established among the physicians. Hence each physician is exposed to peer pressure. The hospital management (the principal) is not able to observe each individual physician's production, but the department's output (number of patients treated) can be observed and verified. Furthermore, the hospital management can identify if an individual is a specialist or an assistant physician, and treats this information as a signal of the physician's productivity (or talent). Moreover, the fact that a physician is either an assistant or a specialist is verifiable information, such that the hospital management can use this information when determining an individual's incentive scheme.

The general conclusion we obtain regarding economic incentives is that the principal always chooses to give less productive agents the strongest incentives. That is, less productive agents are offered a salary scheme that is more responsive to the team output than it is the case for more productive agents. Furthermore, we show that the principal is able to implement the unique first-best solution if the agents are risk-neutral. In this solution less productive agents exert less effort, and all agents experience peer pressure.

To understand the intuition behind these results note that while it is the case that peer pressure can encourage additional effort from co-workers, peer pressure also imposes costs on the other workers. These costs must be compensated by the principal. Hence, peer pressure causes the principal to tie the effort levels of the agents more closely together relative to the case where peer effects are absent. In a situation with agency, i.e., when the principal cannot write contracts directly on the agents' effort level, the principal's only way to tie the effort levels of different agents together is by using economic incentives. Since the agents respond by exerting more effort when exposed to stronger incentives, the principal induces more effort from the low-productive workers by increasing their incentives. Similarly, the principal reduces the incentives of the high-productive workers compared with a situation without

[1] In this respect we follow Spence's (1973, 1974) idea of job-market signaling.

peer effects, entailing that these agents choose lower effort in equilibrium.

Our analyzes of peer pressure is related to the work of Barron and Gjerde (1997) and of Huck, Kübler, and Weibull (2002). The first of these papers develops an agency model of peer pressure to identify factors that affect the extent of mutual monitoring. That is, they analyze how the incentive scheme presented by the principal affects the agents' incentives to costly monitor other agents' effort choices. Since monitoring efforts are costly for the agents, the principal has to compensate agents for their monitoring costs. Barron and Gjerde (1997) establish conditions under which the principal reduces the incentives given to the agents as a mean to lower the monitoring efforts. We do not include monitoring in our model. This is because we do not want to exclude the possibility that peer effects arise from internal pressure (as opposed to external pressure). Here, internal pressure refers to situations where an individual experiences disutility from not satisfying the social norm, although his peers cannot identify him (Kandel and Lazear, 1992). Alternatively, if the peer effects arise from external pressure, it might be the case that monitoring is costless so that the principal does not have to compensate the agents for their monitoring efforts.

Huck, Kübler, and Weibull (2002) do also focus on the interplay of economic incentives and social norms. More specifically, these authors raise the question if the interplay of social norms and economic incentives implies that multiple equilibria may exists in teams of identical agents.[2] We do however follow the avenue chosen by Kandel and Lazear (1992) and rule out multiplicity by imposing certain convexity restrictions on the model. Furthermore we note that both these papers consider the case where agents have identical productivity.

The paper is organized as follows. In section 2 we outline the model, and section 3 contains the analysis of first-best. Section 4 considers first-best implementation, and section 5 presents some concluding remarks.

2 The Model

Imagine a situation where two groups of agents work for a principal. The two groups differ with respect to their marginal productivity. Each agent decides on the effort he would like to exert on a single task. Making his decision, he will weigh his marginal gains from the contract provided by the principal and his marginal cost, which is assumed to arise from exerting effort and

[2] Intuitively, multiplicity arises when a social norm introduces a coordination problem into the agents' effort choices: Choose high (low) effort if you expect others to exert high (low) effort.

from peer pressure. Taking the agents' reaction into account, the principal decides on the contract offered to each agent.

To fucus of the effects of different productivity among agents we imagine that individuals from one group only interact with individuals from the other group, respectively. Correspondingly, they observe the effort level only of individuals of the other group. As a result, peer pressure of an individual relates to how his own effort compares to a measure of the effort level of the other group. To facilitate comparison with Encinosa, Gaynor, and Rebitzer (1997) and Huck, Kübler, and Weibull (2002) we let this measure be the average effort level of the individuals of the other group. We denote the two groups by $I = \{1, ..., k\}$ and $J = \{k+1, ..., n\}$, where n is the total number of agents, and $1 \leq k < n$. Whenever e_h represents the effort level of an individual of the one group, say $h \in I$, then let $\overline{e_{-H}}$ represent the average effort of individuals in the other group, i.e. $\overline{e_{-I}} = \frac{1}{n-k} \sum_{j \in J} e_j$ and $\overline{e_{-J}} = \frac{1}{k} \sum_{i \in I} e_i$.

Let each risk-neutral agents' payoff function be given by[3]

$$A_h + \alpha_h f(e_1, ..., e_n) - c(e_h) - P(e_h - \overline{e_{-H}}), \quad \forall h \in I \cup J, \tag{1}$$

where $f(e_1, ..., e_n)$ is the production function, $P(\cdot)$ is the peer pressure function and $A_h + \alpha_h f(e_1, ..., e_n)$ is agent h's salary given his effort level e_h and given the incentive contract (A_h, α_h) provided by the principal. We assume expected production to be

$$y = f(e_1, ..., e_n) = f_I \left(\sum_{i \in I} e_i \right) + f_J \left(\sum_{j \in J} e_j \right),$$

where f_H is the expected marginal productivity (or talent) of agents from group H, $H = I, J$. We imagine that expected individual productivity is related to certain group-specific characteristics of the agents that are observable for the principal. Examples of such characteristics include an agent's year of schooling (master or Ph.D. level), his level of training (number of job-specific courses taken) or his position (laboratory assistant or professor). Since these types of information can easily be verified by a third party, it is possible for the principal to tie individual pay to expected individual productivity. In addition, the principal observes team output, while she cannot observe the agents' choice of effort. Without loss of generality, let group J contains the more productive agents, i.e. $f_J > f_I \geq 0$.

[3]We choose to focus on risk-neutrality to highlight the effects of peer pressure on incentives. In section 5 we comment on how the analysis will be affected if agents are risk-averse.

Each agent's cost of exerting effort $e \geq 0$ is $c(e)$ which we assume to satisfy the following assumption:

Assumption (C) *Let the cost function $c(e)$ be twice differentiable, increasing, strictly convex and display zero marginal cost at the origin, i.e.* *(i)* $c'(e_h) > 0$, *(ii)* $c''(e_h) > 0$ *for* $e_h > 0$ and *(iii)* $c'(0) = 0$.

Notice that (i) and (ii) imply that $c(e)$ is unbounded; for all $0 \leq \widehat{c} < \infty$ there exists some $e \in [0, \infty)$ such that $c(e) > \widehat{c}$.

The peer pressure function captures that each agent h feels a social pressure to exert an effort level similar to that of the other agents.

Assumption (P) *Suppose the peer pressure function $P(z)$, where* $z = e_i - \overline{e_J}$ for $i \in I$ and $z = e_j - \overline{e_I}$ for $j \in J$, *is twice differentiable and satisfies (i)* $P(0) = 0$, *(ii)* $P'(0) = 0$, *(iii)* $P''(z) \geq 0$ for $z \geq 0$ *and* $P''(z) > 0$ *for* $z < 0$, *and (iv)* $P(-z) \geq P(z)$ $\forall z > 0$.

Part (i) states that a single agent does not fell peer pressure if his effort is identical to the effort level of the other agents. Parts (ii) and (iii) guarantee that peer pressure is minimized in that case (possibly, with existing other minimizers, z, which necessarily have to be positive). Finally, part (iv) states that falling below the social norm induces no lower peer pressure than exceeding it by the same absolute amount. Notice that the agent with the highest effort level might not experience peer pressure at all. Example 2 below represents such a case.

To illustrate the flexibility of Assumption (P), we include the two following examples:

Example 1 *Conformity preferences (Huck et al, 2002). Suppose* $P_A(z) = (e_h - \overline{e_{-H}})^2$. *With conformity preferences, exerting higher effort is as bad as exerting lower effort that is lower by the same amount.*

Example 2 *Loss aversion (Encinosa et al, 1997). Suppose* $P_B(e_h - \overline{e_{-H}}) = \rho \cdot (\min\{(e_h - \overline{e_{-H}})/2, 0\})^2$. *Under loss aversion, peer pressure is present only for effort below average. The parameter $\rho > 0$ measures the intensity of peer pressure.*

Let the agents choose their effort level with the objective of maximizing individual payoff,

$$\max_{e_h \geq 0} \{A_h + \alpha_h f(e_1, ..., e_n) - c(e_h) - P(e_h - \overline{e_{-H}})\} \quad \forall h \in I \cup J.$$

The corresponding first-order conditions are

$$\alpha_h f_h(e_1, ..., e_n) - c'(e_h) - P'(e_h - \overline{e_{-H}}) = 0 \quad \forall h \in I \cup J, \tag{2}$$

where $y'(\cdot)$ denotes the first-order derivative of any function $y(\cdot)$.

The first-order conditions define effort levels as functions of incentives, $e_h = e_h(\alpha_I, \alpha_J)$, $h \in I \cup J$, (i.e., the agents' incentive constraints). The agents' participation constraints are given by

$$A_h + \alpha_h f(\cdot) - c(e_h) - P(e_h - \overline{e_{-H}}) \geq u_h^0 \quad \forall h \in I \cup J,$$

where u_h^0 represents the monetary value of some exogenous outside option for agent $h \in I \cup J$.

The principal, who only observes aggregate production, is risk-neutral and maximizes her (expected) payoff,

$$f(e_1, ..., e_n) - k\left[A_I + \alpha_I f(\cdot)\right] + (n-k)\left[A_J + \alpha_J f(\cdot)\right]$$

subject to the participation constraints and taking into account the agents' optimal response to the incentives α_h, $h = I, J$.

The principal's problem of maximizing her expected payoff subject to the incentive and participation constraint is equivalent to maximizing the total collective surplus of the agents and the principal taking into account the agents' optimal response to the incentives she provides. Assuming that the participation constraints are satisfied in equilibrium, the principal's maximization problem is

$$\begin{aligned} &\max_{\alpha_I, \alpha_J} \left\{ f(e_1, ..., e_n) - \sum_h c(e_h) - \sum_h P(e_h - \overline{e_{-H}}) \right\} \\ &s.t. \quad e_h = e_h(\alpha_I, \alpha_J) \quad h \in I \cup J. \end{aligned} \tag{3}$$

The corresponding first-order conditions are given by

$$\begin{aligned} &f_I \frac{\partial e_i}{\partial \alpha_H} + f_J \frac{\partial e_j}{\partial \alpha_H} - c'(e_i)\frac{\partial e_i}{\partial \alpha_H} - c'(e_j)\frac{\partial e_j}{\partial \alpha_H} - \sum_{i \in I} P'(e_i - \overline{e_j})\frac{\partial (e_i - \overline{e_j})}{\partial \alpha_H} \\ &- \sum_{j \in J} P'(e_j - \overline{e_I})\frac{\partial (e_j - \overline{e_I})}{\partial \alpha_H} - \sum_{h \in I \cup J} P'(e_h - \overline{e_{-H}})\frac{\partial (e_h - \overline{e_{-H}})}{\partial \alpha_H} = 0 \quad \forall H = I, J. \end{aligned}$$

These equations implicitly define the optimal incentives for this principal-agent problem. Without knowing the functional form of the cost and peer pressure it is not possible to determine an explicit solution. We are however able to establish that it is always optimal for the principal to give stronger incentives to the less productive agent, i.e., $\alpha_J < \alpha_I$. First, we prove existence of unique first-best effort levels.

3 First-Best Effort Levels

Suppose it is possible for the principal to write contracts on effort levels directly. From the principal's objective function, we can derive the following characterization of first-best effort levels

$$f_i - c'(e_i) - P'(e_i - \overline{e_J}) + \frac{1}{k}\sum_{j\in J} P'(e_j - \overline{e_I}) = 0 \quad \forall i \in I \tag{4}$$

$$f_j - c'(e_j) - P'(e_j - \overline{e_I}) + \frac{1}{n-k}\sum_{i\in I} P'(e_i - \overline{e_J}) = 0 \quad \forall j \in J. \tag{5}$$

Since the principal's objective function is symmetric within groups of players, existence of a maximizer to (3) implies existence of an intra-group symmetric solution to (3). Moreover, the principal is indifferent between all these solutions. Therefore, it is sufficient (and convenient) to show existence and uniqueness of an symmetric intra-group solution, i.e. where $e_i^* = e_I^*$ for all $i \in I$ and $e_j^* = e_J^*$ for all $j \in J$.

Proposition 1 *Suppose the principal-agent problem satisfies Assumptions (C) and (P). Then there exists a unique pair of intra-group symmetric first-best effort levels* (e_I^*, e_J^*)*. Moreover, the less productive player exerts less effort (i.e.,* $f_J > f_I \geq 0$ *implies* $e_J^* > e_I^* > 0$*).*

The above proposition states that, in first-best, more productive agents should exert higher effort. Moreover, even if the less productive group of agents is not productive at all, i.e. if $f_I = 0$, it will be socially optimal to induce him to exert positive effort.

This implies that there will always be peer pressure in social optimum. Notice that it would be possible for the principal to completely eliminate the externality arising from peer pressure. She could simply require both types of agents to exert identical effort. Nevertheless, Proposition 1 tells us that it would not be optimal for the principal to do so. The main reason is that eliminating peer pressure would require identical effort levels, $e_I = e_J$. In that case marginal cost would be the same for both groups of agents, while peer pressure and hence marginal peer pressure would be zero. Therefore, marginal cost cannot equate to expected marginal productivity for *both* group of agents. Identical effort levels can thus never be first-best.

We now give the proof of Proposition 1.

Proof of Proposition 1. We first prove the statement regarding the ranking of efforts.

(*Effort-ranking*) First, suppose $f_J > f_I \geq 0$ and $e_I^* = e_J^*$. From Assumption (P) it follows that $P'(e_I^* - \overline{e_J^*}) = P'(e_J^* - \overline{e_I^*}) = P'(0) = 0$. Therefore, the first-order conditions (5) reduce to $f_I = c'(e_I^*)$ and $f_J = c'(e_J^*)$. Moreover, $e_I^* = e_J^*$ implies $c'(e_I^*) = c'(e_J^*)$ and hence

$$f_I = c'(e_I^*) = c'(e_J^*) = f_J,$$

which contradicts $f_J > f_I$. Hence, we conclude that $e_J^* \neq e_I^*$.

Suppose now $f_J > f_I \geq 0$ and that $e_I^* > e_J^*$ were first-best effort levels. Then the principal could increase his pay-off by inducing agents $i = 1$ and $j = n$ to switch effort levels, i.e. $\widehat{e}_1 = e_J^*$ and $\widehat{e}_n = e_I^*$ (while $\widehat{e}_i = e_I^*$ for $i = 2, \dots, k$ and $\widehat{e}_j = e_J^*$ for $j = k+1, \dots, n-1$). For, it follows that

$$\sum_{h \in I \cup J} c(e_h^*) = \sum_{h \in I \cup J} c(\widehat{e}_h) \qquad \text{and}$$
$$\sum_{h \in I \cup J} P(e_h^* - \overline{e_{-H}^*}) = \sum_{h \in I \cup J} P(\widehat{e}_h - \overline{\widehat{e}_{-H}}).$$

Moreover, $0 \leq f_I < f_J$ and $e_J^* < e_I^*$ imply $f_I(e_I^* - e_J^*) < f_J(e_I^* - e_J^*)$ and hence

$$f(e_I^*, e_J^*) - f(\widehat{e}_I, \widehat{e}_J) = f_I e_I^* + f_J e_J^* - (f_I e_J^* + f_J e_I^*) < 0,$$

in contradiction to (e_I^*, e_J^*) having been chosen optimally.

Finally, to show $e_I^* > 0$, notice that $e_I^* = 0$ would imply $e_J^* \neq 0$ (if not so then $e_J^* = e_I^* = 0$ would imply that all but the first expression in (4) vanish so that equation (4) could not be satisfied). Hence

$$c'(e_I^*) + P'(e_I^* - \overline{e_J^*}) - \frac{n-k}{k} P'(e_J^* - \overline{e_I^*}) = P'(-e_J^*) - \frac{n-k}{k} P'(e_J^*) < 0. \quad (6)$$

Here, the inequality holds true, because $P'(-z) - \frac{n-k}{k} P'(z)$ is decreasing in z and equals zero for $z = 0$. From $f_I \geq 0$, it hence follows that the left-hand side of equation (5) is strictly positive, which yields a contradiction.

We now prove the statements regarding existence and uniqueness.

(*Existence and Uniqueness*) Define

$$\varphi(e_I, e_J) := c'(e_I) + P'(e_I - \overline{e_J}) - \frac{n-k}{k} P'(e_J - \overline{e_I})$$

and

$$\psi(e_I, e_J) := c'(e_J) + P'(e_J - \overline{e_I}) - \frac{k}{n-k} P'(e_I - \overline{e_J}),$$

where in intra-group symmetric equilibria we have $\overline{e_I} = e_I$ and $\overline{e_J} = e_J$.

Notice that $\varphi(e_I, e_J)$ is increasing in e_I and decreasing in e_J, because $c'(y)$ is increasing in y and $P'(z) - \frac{n-k}{k}P'(-z)$ is increasing in z. Similarly, $\psi(e_I, e_J)$ is decreasing in e_I and increasing in e_J. Moreover, by Assumptions (C) and (P) both functions are differentiable.

Given these definitions, we can write (5) equivalently as

$$\begin{aligned}\varphi(e_I, e_J) &= f_I \quad \text{and} \\ \psi(e_I, e_J) &= f_J.\end{aligned}$$

Define the functions $e_I(e_J)$ and $e_J(e_I)$ implicitly by

$$\varphi(e_I(e_J), e_J) = f_I \quad \text{and} \quad \psi(e_I, e_J(e_I)) = f_J, \qquad \text{respectively.} \tag{7}$$

By Assumptions (C) and (P), both functions are continuously differentiable. In order to establish existence of a unique solution to (5), it is hence sufficient to show that $e_I(e_J)$ and $e_J(e_I)$ have a positive interception, $e_i(0) > 0$, that they intersect with the $e_I = e_J$-line and that they have a slope less than one, $e_i'(e_j) < 1$ (see also Figure 1).

First, to see $e_I(0) > 0$, notice that (i) $\varphi(e_I, 0)$ is (strictly) increasing and continuous in e_I, (ii) $\varphi(e_I, 0) = 0$ for $e_I = 0$, and (iii) there exists $\widehat{e} < \infty$ such that $\varphi(\widehat{e}, 0) > f_I$. By the intermediate value theorem there exists $\underline{e}_I \in (0, \widehat{e})$ such that $\varphi(\underline{e}_I, 0) = f_I$. Uniqueness follows from monotonicity of $\varphi(e_I, 0)$. (Observe that we can apply the same argument to any arbitrary $e_J \geq 0$. It hence follows that the functions $e_I(e_J)$ and $e_J(e_I)$ are well defined.)

Second, the functions $e_I(e_J)$ and $e_J(e_I)$ intersect with the (e_I=e_J)-line, respectively, since $e_I = e_J$ implies $\varphi(e_I, e_J) = c'(e_I)$ and $\psi(e_I, e_J) = c'(e_J)$. Consequently, the system (7) for $e_I = e_J$ reduces to $c'(e_I) = f_I$ and $c'(e_J) = f_J$. This system has a (finite) solution because $c'(\cdot)$ is strictly increasing.

Third, the derivative $e_I'(e_J)$ can be calculated using the implicit differentiation theorem,

$$e_I'(e_J) = \frac{P''(e_I - e_J) + \frac{n-k}{k}P''(e_J - e_I)}{c''(e_I) + P''(e_I - e_J) + \frac{n-k}{k}P''(e_J - e_I)}.$$

Obviously, Assumptions (C) and (P) imply $e_I'(e_J) \in [0, 1)$. Since the properties of $e_J(e_I)$ can be shown similarly, this completes the second part of the proof. ■

Insert Figure 1 about here

To shed light on the comparative statics of our model, the following proposition establishes that the socially optimal effort levels increase monotonically in productivity.

Proposition 2 *First best effort levels, e_I^* and e_J^*, increase with each productivity, f_I and f_J.*

Proof. Suppose $f_J > f_I \geq 0$. We prove the claim for effort level e_I^* and an increase in f_I and f_J. Recall the functions $e_I(e_J)$ and $e_J(e_I)$ implicitly defined in (7) and consider an increase in f_I first. By definition, the function $e_J(e_I)$ is not affected by the increase in f_I. On the other hand, the function $e_I(e_J)$ now assigns a higher value to each fixed $e_J \geq 0$. One only has to see that an increase in $f_I = \varphi(e_I, e_J)$ implies a strictly higher value of e_I for each fixed $e_J \geq 0$, because $\varphi(e_I, e_J)$ is increasing in e_I. Consequently, we have for the 'new' function $\widetilde{e}_I(e_J)$ that $\widetilde{e}_I(e_J) > e_I(e_J)$, for all $e_J \geq 0$. Since $\widetilde{e}_I(e_J)$ has a slope less than one, $\widetilde{e}'_I(e_J) < 1$, there still exists a unique solution, (e_I^{**}, e_J^{**}), and this has the property $e_I^* < e_I^{**}$ and $e_J^* < e_J^{**}$.

Second, consider an increase in f_J. Similar to the above, it is now the function $e_I(e_J)$ that is not affected by this increase. The function $e_J(e_I)$ assigns a higher value to each fixed $e_J \geq 0$, because $\psi(e_I, e_J)$ is increasing its second argument. Then the aforementioned graphical argument establishes existence and uniqueness of the new solution, (e_I^{**}, e_J^{**}), which has the property $e_J^{**} > e_I^{**}$. ■

To illustrate the effect of increasing peer pressure and increasing cost, respectively, we temporarily introduce a peer pressure parameter $\rho > 0$ and a cost parameter $\gamma > 0$ into the objective functions of the agents and the principal:

$$\max_{e_h \geq 0} \{A_h + \alpha_h f(e_1, ..., e_n) - \gamma c(e_h) - \rho P(e_h - \overline{e_{-H}})\} \quad \forall h \in I \cup J \ (agent).$$

$$\max_{\alpha_I, \alpha_J} \left\{ f(e_1, ..., e_n) - \gamma \sum_h c(e_h) - \rho \sum_h P(e_h - \overline{e_{-H}}) \right\} \qquad (principal)$$

$$s.t. \quad e_h = e_h(\alpha_I, \alpha_J) \quad h \in I \cup J$$

Note that doing so is without loss of generality, since the functions $\widetilde{c}(e_h) = \gamma c(e_h)$ and $\widetilde{P}(z) = \rho P(z)$ satisfy Assumption (C) and (P), respectively, if and only if the functions $c(e_h)$ and $P(z)$ satisfy these assumptions. Therefore, Propositions (1) and (2) and the results in the following section cover this case.

Proposition 3 *(i) The first-best effort level of the less productive agents, e_I^*, increases in the peer pressure parameter ρ, while the first-best effort level of more productive agents, e_J^*, decreases with ρ.*
(ii) Both first-best effort levels, e_I^* and e_J^*, decrease with the cost parameter γ.

Proof. See the Appendix. ■

4 First-Best Implementation

In this section we analyze the case of agency, i.e., the case where the principal cannot write contracts directly on the effort levels. We first show that for any given incentives (α_I, α_J) there exists a unique pair of effort levels, (e_I, e_J), which the agents will choose. Subsequently, we turn towards analyzing the principals problem of determining the optimal incentives.

Proposition 4 *Suppose the principal-agent problem satisfies Assumptions (C) and (P). Then, for any given pair of incentives (α_I, α_J) such that $\alpha_I, \alpha_J > 0$, there exists a unique pair of effort levels (e_I, e_J), $e_h \geq 0$ $\forall h \in I \cup J$. Consequently, the $e_i(\alpha_I, \alpha_J)$ are well defined functions.*

Proof. Fix $\alpha_I, \alpha_J > 0$. Consider the agents' first-order conditions. Using the definitions provided in the proof of Proposition 1, one can rewrite these conditions as

$$\varphi(e_I, e_J) = \alpha_I f_I \quad \text{and}$$
$$\psi(e_I, e_J) = \alpha_J f_J.$$

Similar to the proof of Proposition 1, these conditions implicitly define functions $\widetilde{e}_I(e_J)$ and $\widetilde{e}_J(e_I)$ such that

$$\varphi(\widetilde{e}_I(e_J), e_J) = \alpha_I f_I \quad \text{and}$$
$$\psi(e_I, \widetilde{e}_J(e_I)) = \alpha_J f_J.$$

The rest of the proof can be established along the lines of Proposition 1. ■

How incentives relate to effort levels, will be analyzed in Lemma 1 below. At this stage we merely remark that the comparative statics properties of the first-best analysis allows us to conclude that each effort level increases with each single incentive, α_I and α_J.

The following Theorem establishes that the principal can implement the first-best solution. To this end she gives stronger incentives to the less productive agents. More precisely, the less productive agents receive incentives above the 100 percent level, while the more productive agents face incentives strictly below 100 percent. In this regard notice that incentives of 100 percent (given to both types of agents) represent the first-best solution in absence of peer pressure.

Theorem 1 *Suppose the principal-agent problem satisfies Assumptions (C) and (P). Then, the principal can implement the first-best effort levels (e_I^*, e_J^*) such as characterized by equation (5). The implementation of this solution requires that $\alpha_I \geq 1 > \alpha_J$.*

To prove the Theorem the following Lemma is helpful. It derives conditions that provide the promised link between incentives and effort levels. In particular, it shows that the principal will always implement incentives that induce more productive agents to exert higher effort.

Lemma 1 *Suppose the principal-agent problem satisfies Assumptions (C) and (P). Then, (i)* $e_I \leq e_J$ *if and only if* $\alpha_I f_I \leq \alpha_J f_J$*, (ii)* $\alpha_I f_I \leq \alpha_J f_J$*, (iii)* $e_I \neq e_J$*, and (iv)* $e_I > 0$*. From (i) to (iii) it thus follows that* $e_I < e_J$*.*

Proof of Lemma 1. *Statement (i)* First, suppose $e_I \leq e_J$ and $\alpha_I f_I > \alpha_J f_J$. It follows that $c'(e_I) + P'(e_I - \overline{e_J}) \leq c'(e_J) + P'(e_J - \overline{e_I})$, which implies a contradiction because of $c'(e_I)+P'(e_I-\overline{e_J}) = \alpha_I f_I > \alpha_J f_J = c'(e_J)+P'(e_J-\overline{e_I})$. To show the converse, suppose $e_I > e_J$. It follows that $c'(e_I) + P'(e_I - \overline{e_J}) > c'(e_J) + P'(e_J - \overline{e_I})$. Because of the agents' first-order conditions this is equivalent to $\alpha_I f_I > \alpha_J f_J$.

Statement (ii) Suppose $\alpha_I f_I > \alpha_J f_J$ (or equivalently $e_I > e_J$). Then the principal could induce two agents – one of each group, say $i = 1$ and $j = n$ – to switch effort-levels by choosing $\overline{\alpha}_n = \alpha_I f_I / f_J$ and $\overline{\alpha}_1 = \alpha_J f_J / f_I$. The switch in effort levels does neither affect total cost nor total peer pressure, but increases production. Hence $\alpha_I f_I > \alpha_J f_J$ cannot be optimal.

Statement (iii) If $e_I = e_J$, then peer pressure is zero for both agents, and marginal costs are equal across players. Since marginal cost equals marginal productivity, $f_I < f_J$ implies a contradiction.

Statement (iv). From statements (i) to (iii), it follows that $e_I < e_J$. Hence, $P'(e_I - \overline{e_J}) < 0$. Then the first-order condition of agents from group I implies $c'(e_I) - \alpha_I f_I > 0$. From $\alpha_I f_I \geq 0$, it follows that $c'(e_I) > 0$. Because of $c'(0) = 0$, we obtain $e_I > 0$. ∎

Proof of Theorem 1. Inserting the agents' first-order conditions given in equation (2) into the first-order conditions that characterize first-best effort levels (5) yields

$$\begin{aligned} (1-\alpha_I) f_I &= -\frac{n-k}{k} P'(e_J^* - \overline{e_I^*}) \qquad \forall i \in I \\ (1-\alpha_J) f_J &= -\frac{k}{n-k} P'(e_I^* - \overline{e_J^*}) \qquad \forall j \in J \end{aligned} \tag{8}$$

These equations allow us to calculate the pair of incentives (α_I, α_J) that implements first-best. Notice that the corresponding pair of first-best effort levels is uniquely determined because of Proposition 4. Since from Lemma 1 it follows that $e_J^* > e_I^*$, we have $P'(e_J^* - e_I^*) \geq 0 > P'(e_I^* - e_J^*)$. Thus, (8) implies $\alpha_I \geq 1 > \alpha_J$. ∎

5 Conclusion

We have investigated a principal-agent model, where one principal offers incentive contracts to two groups of agents with different productivity. It turns out that it is always socially optimal to induce the more productive agents to exert higher effort. We then established that it is indeed possible for the principle to implement first-best. To this end, however, the principal has to give lower incentives to the more productive agents than she gives to the less productive agents.

To understand the intuition behind these results note that while it is the case that peer pressure can encourage additional effort from co-workers, peer pressure also imposes costs on the other workers. These costs must be compensated by the principal. Hence, peer pressure causes the principal to tie the effort levels of the agents more closely together relative to the case where peer effects are absent. In a situation with agency, i.e., when the principal cannot write contracts directly on the agents' effort level, the principal's only way to tie the effort levels of different agents together is by using economic incentives. Since the agents respond by exerting more effort when exposed to stronger incentives, the principal induces more effort from the low-productive workers by increasing their incentives. Similarly, the principal reduces the incentives of the high-productive workers compared with a situation without peer effects, entailing that these agents choose lower effort in equilibrium.

So far, we have chosen to set aside issues related to risk-sharing between the principal and the agents. Our motivation for doing so was to highlight the effects of peer pressure on the optimal incentives. This allowed us to compare the optimal incentives to the one hundred percent compensation rule that is obtained in the principal-agent literature when risk-neutral agents face a linear compensation scheme. We now comment on how our main result will change if the agents are risk-averse.

One way to introduce risk-aversion in our model is to follow Holmstrom and Milgrom (1991) and assume that the agents' utility functions are exponential and that all random variables are normally distributed. With these assumptions and with linear compensations, the agents' certainty equivalence utility are as given in equation 1 with an additional term subtracting the risk cost. By maximizing the principal's objective function, and taking the risk-averse agents' response into account, we get the following well known result for the case where peer pressure is absent: The principal chooses to lower the incentives below the 100 percent rule. The reason is simply that stronger incentives expose the agents to more risk, and this is costly for the principal which has to compensate them for their risk costs. Suppose now that the principal has to decide on the incentives taking *both* peer effects and risk into account. First of all we see that there is no conflict between peer pressure and risk costs for the high-productive agents in that both effects make it optimal to lower these agents' incentives. For the low-productive group, however, the principal has to realize that strengthening their incentives affects her utility in two opposite ways. First, stronger incentives reduces peer pressure. This is beneficial for the principal. Secondly, stronger incentives expose these workers for more risk which has to be compensated by the principal. Hence we see that the strength of the incentives will depend on the relative strength of peer pressure and risk-averion. If the former effect dominates the results in this paper continue to hold since the gain of reducing peer pressure outweighs the cost of risk compensation. On the other hand, if risk aversion is relatively strong compared to peer pressure, the principal will set incentives mainly to correct for the risk cost. For sufficiently, relatively strong risk aversion our main result will not hold true anymore.

Finally, we note that social welfare was lower in the presence of peer pressure than in its absence. With regard to the organization of teams, this implies that one should organize teams such that agents of similar productivity work in the same team. Whether a team as such remains an optimal form of work organization in the presence of peer pressure and under which conditions this is the case, is a question we investigate in another paper.

References

Barron, J. M. and K. P. Gjerde (1997). Peer pressure in an agency relationship. *Journal of Labor Economics 15*, 234–254.

Encinosa, W. E., M. Gaynor, and J. B. Rebitzer (1997, March). The sociology of the groups and the economics of incentives: Theory and evidence on compensation systems. Working Paper 5953, NBER.

Falk, A., U. Fischbacker, and S. Gächter (2002). Isolation social interaction effects. Mimeo, University of Zurich.

Falk, A. and A. Ichino (2003). Clean evidence on peer effects. Mimeo, University of Zurich.

Holmstrom, B. and P. Milgrom (1991). Multitask principal-agent analyses: Incentive contracts, asset ownership, and job design. *Journal of Law, Economics and Organization 7*, 24–52.

Huck, S., D. Kübler, and J. Weibull (2002). Social norms and economic incentives in firms. Technical report, University College London.

Kandel, E. and E. P. Lazear (1992). Peer pressure and partnerships. *Journal of Political Economy 100*, 801–817.

Spence, A. M. (1973). Job market signaling. *Quarterly Journal of Economics 87*, 355–374.

Spence, A. M. (1974). Competitive and optimal responses to signaling: An analysis of efficiency and distribution. *Journal of Economic Theory 8*, 296–332.

Appendix

Proof of Proposition 3. To start with, observe that first-best effort levels are characterized by the following pair of equations:

$$
\begin{aligned}
f_I &= \varphi\left(e_I, e_J; \gamma, \rho\right) := \gamma c'\left(e_I\right) + \frac{\rho}{k}\left[kP'(e_I - e_J) - (n-k)\, P'\left(e_J - e_I\right)\right] \\
f_J &= \psi(e_I, e_J; \gamma, \rho) := \gamma c'(e_J) + \frac{\rho}{n-k}\left[(n-k)\, P'(e_J - \overline{e_I}) - \frac{k}{n-k} P'(e_I - \overline{e_J})\right].
\end{aligned}
$$

Denote the corresponding solution by $\left(e_I^*\left(\gamma, \rho\right), e_J^*\left(\gamma, \rho\right)\right)$.

First, we analyze the effect of increasing peer-perssure $\left(\rho \uparrow\right)$. To this end, define

$$
M = \begin{pmatrix} \frac{\partial \varphi}{\partial e_I} & \frac{\partial \varphi}{\partial e_J} \\ \frac{\partial \psi}{\partial e_I} & \frac{\partial \psi}{\partial e_J} \end{pmatrix} \quad \textit{and} \quad M_1 = \begin{pmatrix} -\frac{\partial \varphi}{\partial \rho} & \frac{\partial \varphi}{\partial e_J} \\ -\frac{\partial \psi}{\partial \rho} & \frac{\partial \psi}{\partial e_J} \end{pmatrix}.
$$

Then by the Implicit Function Theorem, $\frac{\partial e_I}{\partial \rho}$ can be expressed as $\frac{\partial e_I}{\partial \rho} = \frac{\det M_1}{\det M}$.

First we note that

$$
\begin{aligned}
\det M &= \frac{\partial \varphi}{\partial e_I}\frac{\partial \psi}{\partial e_J} - \frac{\partial \varphi}{\partial e_J}\frac{\partial \psi}{\partial e_I} \\
&= \left[\gamma c''(e_I) + \rho \frac{1}{k}\left[kP''\left(e_I - e_J\right) + (n-k)\, P''\left(e_J - e_I\right)\right]\right] \\
&\quad \times \left[\gamma c''(e_J) + \rho \frac{1}{n-k}\left[(n-k)\, P''\left(e_J - e_I\right) + P''\left(e_I - e_J\right)\right]\right] \\
&\quad -\rho^2 \frac{1}{k\,(n-k)}\left[kP''\left(e_I - e_J\right) + (n-k)\, P''\left(e_J - e_I\right)\right] \\
&= \gamma^2 c''(e_I) c''(e_J) + \gamma\rho \frac{1}{n-k} c''(e_I)\left[(n-k)\, P''\left(e_J - e_I\right) + kP''\left(e_I - e_J\right)\right] \\
&\quad + \gamma\rho \frac{1}{k} c''(e_J)\left[(n-k)\, P''\left(e_J - e_I\right) + kP''\left(e_I - e_J\right)\right] \\
&> 0.
\end{aligned}
$$

Second, we determine $\det M_1$.

$$\begin{aligned}
\det M_1 &= -\frac{\partial \varphi}{\partial \rho}\frac{\partial \psi}{\partial e_J} + \frac{\partial \varphi}{\partial e_J}\frac{\partial \psi}{\partial \rho} \\
&= -\left[\frac{1}{k}\left[kP'\left(e_I - e_J\right) - \left(n-k\right)P'\left(e_J - e_I\right)\right]\right] \\
&\quad \times \left[\gamma c''(e_J) + \rho \frac{1}{n-k}\left[\left(n-k\right)P''(e_J - e_I) + kP''(e_I - e_J)\right]\right] \\
&\quad + \left[-\rho \frac{1}{k}\left[kP''\left(e_I - e_J\right) + \left(n-k\right)P''(e_J - e_I)\right]\right] \\
&\quad \times \left[\frac{1}{n-k}\left[\left(n-k\right)P'\left(e_J - e_I\right) - kP'\left(e_I - e_J\right)\right]\right] \\
&= \gamma c''(e_J)\frac{1}{k}\left[\left(n-k\right)P'\left(e_J - e_I\right) - kP'\left(e_I - e_J\right)\right] \\
&\quad > 0.
\end{aligned}$$

It thus follows that

$$\frac{\partial e_I}{\partial \rho} = \frac{\det M_1}{\det M} > 0.$$

To see $\frac{\partial e_J}{\partial \rho} < 0$, we combine the two first-order conditions to obtain

$$f_I = \gamma c'\left(e_I\right) + \frac{\rho}{k}\left[-\frac{n-k}{\rho}\left[f_J - \gamma c'\left(e_J\right)\right]\right].$$

This is equivalent to

$$kf_I + \left(n-k\right)f_J = kc'\left(e_I\right) + \left(n-k\right)c'(e_J). \tag{9}$$

Notice that the left hand side of (9) does not depend on $\rho > 0$. Therefore, if an increase in ρ entails an increase in e_I this implies a decrease in e_J (and vice versa), that is

$$\frac{\partial e_I}{\partial \rho} > 0 \Leftrightarrow \frac{\partial e_J}{\partial \rho} < 0,$$

which completes the proof of $\frac{\partial e_J}{\partial \rho} < 0$.

Second, we investigate the effect of increasing cost $(\gamma \uparrow)$. Similarly to the above, we can express $\frac{\partial e_I}{\partial \gamma}$ and $\frac{\partial e_J}{\partial \gamma}$ as

$$\frac{\partial e_I}{\partial \gamma} = \frac{\det N_1}{\det M} \quad \textit{and} \quad \frac{\partial e_J}{\partial \gamma} = \frac{\det N_2}{\det M},$$

respectively, where

$$N_1 = \begin{pmatrix} -\frac{\partial \varphi}{\partial \gamma} & \frac{\partial \varphi}{\partial e_J} \\ -\frac{\partial \psi}{\partial \gamma} & \frac{\partial \psi}{\partial e_J} \end{pmatrix} \quad and \quad N_2 = \begin{pmatrix} \frac{\partial \varphi}{\partial e_I} & -\frac{\partial \varphi}{\partial \gamma} \\ \frac{\partial \psi}{\partial e_I} & -\frac{\partial \psi}{\partial \gamma} \end{pmatrix},$$

and M is defined as above. Recalling $\det M > 0$, we have to show $\det N_1 < 0$ and $\det N_2 < 0$.

$$\begin{aligned} \det N_1 &= -\frac{\partial \varphi}{\partial \gamma}\frac{\partial \psi}{\partial e_J} + \frac{\partial \varphi}{\partial e_J}\frac{\partial \psi}{\partial \gamma} \\ &= c'(e_I)\left[\gamma c''(e_J) + \frac{\rho}{n-k}\left[(n-k)P''(e_J - e_I) + kP''(e_I - e_J)\right]\right] \\ &\quad + \left[-\frac{\rho}{k}\left[kP''(e_J - e_I) + (n-k)P''(e_J - e_I)\right]\right] c'(e_J) \\ &< 0, \\ \det N_2 &= \frac{\partial \varphi}{\partial e_I}\frac{\partial \psi}{\partial \gamma} + \frac{\partial \varphi}{\partial \gamma}\frac{\partial \psi}{\partial e_I} \\ &= -\left[\gamma c''(e_I) + \frac{\rho}{k}\left[kP''(e_I - e_J) + (n-k)P''(e_J - e_I)\right]\right] c'(e_J) \\ &\quad + c'(e_I)\left[\frac{\rho}{n-k}\left[(n-k)P''(e_J - e_I) + kP''(e_I - e_J)\right]\right] \\ &< 0. \end{aligned}$$

Both inequalities hold true because of $c'(\cdot) > 0$, $c''(\cdot) > 0$, and $P'' \geq 0$, respectively. ■

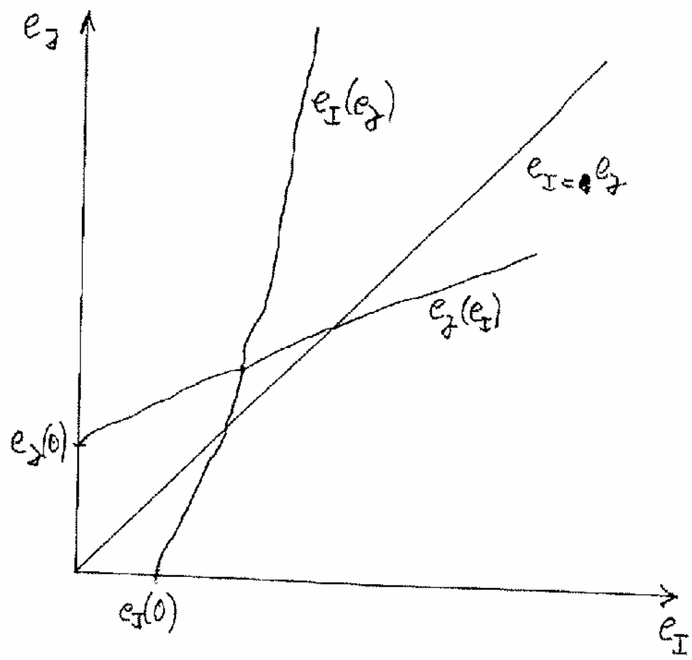

Figure 1