No. 2281

TEAMWORK MANAGEMENT IN AN ERA OF DIMINISHING COMMITMENT

Emmanuelle Auriol, Lambros Pechlivanos
and Guido Friebel

**INDUSTRIAL ORGANIZATION
AND LABOUR ECONOMICS**

Centre for Economic Policy Research

ISSN 0265-8003

TEAMWORK MANAGEMENT IN AN ERA OF DIMINISHING COMMITMENT

Emmanuelle Auriol and Lambros Pechlivanos,
Institut D'Economie Industrielle Université des Sciences Sociales,
Guido Friebel, Stockholm School of Economics

Discussion Paper No. 2281
November 1999

Centre for Economic Policy Research
90–98 Goswell Rd, London EC1V 7RR
Tel: (44 20) 7878 2900, Fax: (44 20) 7878 2999
Email: cepr@cepr.org, Website: http://www.cepr.org

CEPR Discussion Paper No. 2281

November 1999

ABSTRACT

Teamwork Management in an Era of Diminishing Commitment*

This paper studies teamwork management when the principal has different degrees of commitment power. In a model in which both the principal and agents are symmetrically uncertain about the agents' innate abilities, implicit incentives arise when the principal is not able to commit to long-term contracts. The presence of implicit incentives makes the agents more reluctant to behave cooperatively (they actually have incentives to 'sabotage' their colleagues). This forces the principal to offer more 'collectively oriented' incentive schemes than in the presence of commitment, in order to induce the desired level of cooperation. Moreover, teamwork exposes agents to higher risks than the ones they are exposed to in a Taylorist workplace. We find that the optimal team size is constrained by risk considerations and is decreasing in the uncertainty of the production technology and in the time horizon of the team.

JEL Classification: D23, J33, M12
Keywords: teamwork, commitment, team size, collective orientation of incentive schemes, career concerns, sabotage

Emmanuelle Auriol
Lambros Pechlivanos
Institut D'Economie Industrielle
Université des Sciences Sociales,
21 Allée de Brienne
31000 Toulouse
FRANCE
Tel: 33 (5) 61 12 86 20
Email: eauriol@cict.fr

Guido Friebel
SITE
Stockholm School of Economics
Sveavagen 65, Box 6501
S-113 83 Stockholm
SWEDEN
Tel: 46 (8) 736 9681
Fax: 46 (8) 31 6422
Email: guido.friebel@hhs.se

*Discussions with Patrick Bolton, Jacques Cremer, Mathias Dewatripont, Bengt Holmström, Fahad Khalil, Canice Prendergast, Michael Raith, Patrick Rey, Jean Tirole and seminar participants at the 1998 North American Summer Meetings of the Econometric Society in Montreal, at the ESEM 1999 conference in Santiago, and at seminars in Toulouse and Dortmund are gratefully acknowledged. The research of the last two authors was supported by the European Commission under the TMR program. All remaining errors are ours.

Submitted 29 August 1999

NON-TECHNICAL SUMMARY

The organization of the workplace has changed drastically during the last two decades. Teams are replacing the individual as the primary performance unit in the company. It is argued that teams are able to react faster to volatile environments and that teamwork permits a more efficient use of employees' complementary skills. Many corporations hence aim to foster teamwork among their employees. For instance, a 1994 survey of US firms found that in 64% of the responding establishments, at least half of the core workers were involved in employee problem-solving groups, work teams, total quality management practices, job rotation or combinations of these practices.

During the same period of time the employees' trust in their management appears to have diminished substantially. In a survey by the Conference Board of a network of executives from 2,900 firms, two-thirds of the responding companies claimed their employees to be 'highly distrustful'. This feeling of distrust may relate to the perception that there is less job security than in former times. Indeed, the rate of job loss in the US has increased considerably in the 1990s and displaced workers suffer from considerable earnings losses. Moreover, wages appear to have become more volatile. There is empirical evidence that due to greater product market competition, wages in US firms have become more sensitive to the prevailing unemployment and that internal labour markets seem to shield workers less from outside labour market conditions. In general, it appears a rather robust empirical fact that many employees believe their employer has breached some aspect of their employment agreement and that firms are less willing to insure their employees through long-term contracts.

Our paper shows that the occurrence of the above tendencies creates a tension corporations have to deal with. While cooperation is particularly desirable from the point of view of the firm, the firm finds it harder to induce it if employees do not trust their managers' promises, i.e. if managers have no commitment for long-term contracts. We investigate the effect of diminishing managerial commitment on two elements of teamwork management: first, optimal incentive schemes; second, the choice of optimal team size.

In respect to optimal incentive schemes, we show that without commitment for long-term wage contracts (salary paths), employees have an increasing incentive to behave selfishly in order to appear more productive. We base our analysis on the career concerns model introduced by Holmström. Diminishing managerial commitment gives rise to two types of implicit incentives. While career concerns make the agents work harder on their own tasks, they also reduce the willingness of each agent to help his or her colleague. Each agent does not only want to appear as being of high ability, but also better than her colleagues. This kind of ‘passive sabotage’ arises even though explicit incentive schemes actually reward employees for their colleagues’ good performance.

A testable prediction of this analysis is that in order to restore the balance between individually-oriented effort and teamwork, the principal must increase the collective orientation of the explicit incentive scheme. This prediction is corroborated by a recent survey among Fortune 1000 firms. Firms increasingly seek to base their employees’ wages on team efforts and outputs. In particular, this is the case for downsizing firms where presumably employees’ trust in management is very low.

The second contribution of our paper is to show that team size is constrained due to the agents’ risk considerations. Due to the team members’ unknown innate abilities, teamwork exposes each agent to more risks than he or she would be subject to in a traditional, individualistic workplace. In line with the trade-off between incentives and insurance known from the moral hazard literature, we show that due to these risks the principal cannot take advantage of the full efficiency gains associated with the productive synergies of teamwork. In particular, when managers cannot commit to leave the size of teams unchanged in the future, the optimal team size shrinks.

Our analysis sheds some light on the risks associated with policies that aim to develop individual skills and increase individual visibility as a substitute for job security. Such efforts to increase ‘employability’ may involve a serious drawback, since they may exacerbate the tendency for selfish behaviour within the firm, unless they are accompanied by higher-powered team-oriented incentives. Our work is hence also related to recent research that points out that ‘innovative’ Human Resource Management (HRM) practices are effective only if adopted together. Finally, our paper indicates that there are important constraints on the restructuring of firms towards more ‘empowerment’ and teamwork: Even when the individual can be made accountable for her performance, teamwork can be hard to implement due to risk-sharing considerations.

1 Introduction

The organization of the workplace has changed dramatically during the last two decades. Teams are replacing the individual as the primary performance unit in the company. It is argued that teams are able to react faster to volatile environments, and that teamwork permits a more efficient use of employees' complementary skills. Many corporations hence aim to foster teamwork among their employees. For instance, a 1994 survey of US firms found that in 64% of the responding establishments, at least half of the core workers were involved in employee problem-solving groups, work teams, total quality management practices, job rotation or combinations of these practices.[1]

During the same period of time, the trust of employees in their management appears to have diminished substantially. In a survey by the Conference Board,[2] nearly two-thirds of the responding companies claimed their employees to be "highly distrustful". This feeling of distrust may relate to the perception that there is less job security than in former times. Indeed, Farber (1997) finds that the rate of job loss in the US has increased considerably in the 90's and that displaced workers suffer from considerable earnings losses. Moreover, wages appear to have become more volatile. There is some empirical evidence (Bertrand 1998) that, due to greater product market competition, wages in US firms have become more sensitive to the prevailing unemployment, and that internal labor markets seem to shield workers less from outside labor market conditions. In general, it appears a rather robust empirical fact that many employees believe their employer has breached some aspect of their employment agreement (Robinson and Rousseau, 1994) and that firms are less willing to insure their employees through long-term contracts.

Our paper shows that the ocurrence of the above tendencies creates a tension corporations have to deal with. While cooperation is particularly desirable from the point of view of the firm, the firm finds it harder to induce it, if employees do not trust their managers' promises, i.e. if managers have *no commitment* for long-term contracts. We investigate the effect of diminishing managerial commitment on two elements of teamwork management: first, optimal incentive schemes; second, the choice of optimal team size.

[1] Osterman (1994) referred to in Locke, Kochan and Piore (1995). Another survey, referred to in Robinson (1996), reports that 47% of Fortune 1000 companies use teams to some extent, and that 60% plan to increase their use in the near future.

[2] The Conference Board is a network of executives from 2,900 firms and a research organization. The survey is referred to in Mc Shulskis (1997).

In respect to *optimal incentive schemes*, we show that without commitment for long-term wage contracts (salary paths), employees have an increasing incentive to behave selfishly in order to appear more productive. Our analysis is based on Holmström (1982b). When agents' innate ability is neither known to themselves nor to the principal, diminishing managerial commitment gives rise to *career concerns*. These can be disentangled into: a) the standard positive career concerns with respect to the agents' own effort; and b) negative "ratchet" incentives that manifest themselves in a decreased willingness of each agent to help his or her colleague. Each agent does not only want to appear as being of high ability, but also better than her colleagues. This kind of *"passive sabotage"* arises even though explicit incentive schemes actually reward employees for their colleagues' good performance. Notice that in our model, and contrary to Lazear (1989), sabotage incentives do not arise because agents are remunerated according to some relative performance evaluation. Neither are they subject to an implicit rank tournament.

In order to make our result clear, suppose that the manager offers the incentive scheme that is optimal under commitment, without actually being able to commit herself to the contract. Then, the presence of implicit incentives shift each agent's effort from helping her colleagues toward her own individual task. In order to reinstall the desired balance between individually-centered effort and teamwork, the principal must increase the power of the collective component of the incentive scheme and decrease the individualistic component, thus increasing the collective orientation of the offered explicit incentive scheme.

The above prediction of our analysis is corroborated by a survey among Fortune 1000 firms, carried out by Lawler et al (1995). Firms increasingly seek to base their employees' wages on team efforts and outputs. While in 1987, only 7% of the respondents employed gain-sharing plans[3] as an incentive device covering at least 20% of their workforce, this number rose to 16% in 1993. Moreover, in 1993 close to a third of the respondents utilized team-based incentive schemes for at least a fifth of their workers and employees. The study also reports that managers of downsizing firms (who can be assumed to have particularly low commitment power vis-à-vis their employees) are more likely to rely on work-group or team incentives than their colleagues in growing firms.

The second contribution of our paper is to show that *team size* is constrained due to the agents' risk considerations. While teamwork may be desirable because of technological

[3]Gain-sharing plans remunerate team members if they manage to cut costs or increase the output of a team or workgroup.

reasons, it comes at the cost of exposing agents to higher risks than the ones they are exposed to in a traditional, individualistic workplace. Our notion of teamwork is one in which each agent, in addition to performing her "own" task, is called to support her fellow team members in fulfilling their tasks. The principal can induce her agents to support her fellow team members only by tying the compensation of each member of the team to her colleagues' performance.

In this setup, working in a team exposes each agent to two risks: one due to a random component in production for each task, and another due to the team members' unknown innate abilities. Consider an increase in the team size. Then, each agent carries out more tasks than before (i.e., helps more colleagues). To perform an additional task, the agent has to be given additional incentives, i.e., the power of the total incentive scheme increases as well. Thus, performing many tasks exposes each agent to higher risks. In order to sustain the optimal balance between incentives and insurance, the principal must reduce the per-task incentives given to the agent. As a result, the principal does not want to take advantage of the full efficiency gains associated with the productive synergies. Thus, larger teams become less desirable, and consequently, the optimal size of the team is constrained by risk considerations. Applying this idea, we can show that team size in equilibrium shrinks when the principal cannot commit to leave unchanged the size of teams in the future.

Our analysis sheds some light on the risks associated with policies that aim at developping individual skills and increasing individual visibility as a substitute for job security.[4] Such efforts to increase "employability" may involve a serious drawback, since they may exacerbate the tendency for selfish behavior within the firm, unless they are accompanied by higher-powered team-oriented incentives. Our work is hence also related to recent research that points out that "innovative" Human Resource Management (HRM) practices are effective only if adopted together (e.g., Ichniowski, Shaw, and Prennushi (1997)). Finally, our paper indicates that there are important constraints on the restructuring of firms towards more "empowerment" and teamwork: Even when the individual can be made accountable for her performance, teamwork can be hard to implement due to risk-sharing considerations.

The next section relates our model to the existing literature on principal-multiagent relationships and career concerns. Section 3 sets up the model. In Section 4, we analyze the model under managerial commitment, and we derive the main result concerning the

[4] cf. for instance, Kanter (1992).

effects of risk-aversion on the optimal size of teams. In Section 5, the effects of diminishing commitment on teamwork management are highlighted. Section 6 delivers some more implications of our analysis, and finally, Section 7 concludes the paper.

2 Literature Review

There is a subatantial literature on principal-multiagent relationships. Holmström (1982a) and Mookherjee (1984) analyze the role of relative performance evaluation (RPE) on optimal incentive schemes. They argue that the presence of correlation in environments in which several agents work allows the principal to filter out part of the randomness, and hence to reduce the risk her agents are subject to.[5]

Nonetheless, their analysis assumes that there are no technological interactions among agents (i.e., there is no value for teamwork). Lazear (1989) shows that in the presence of such interactions, RPE schemes may lead to the creation of perverse incentives. Agents may actually want to "sabotage" their colleagues. Itoh (1991) allows for the possibility of synergies, and considers the conditions under which the principal induces cooperation among her agents (i.e., promotes teamwork). He shows that the principal induces cooperation among agents if and only if the correlation between the agents' assignments is low, and consequently the potential benefit from not implementing RPE is not important.

In this paper, we employ Itoh's (1991) framework, but we abstract from RPE considerations by assuming that the assignments given to different agents are stochastically independent. Hence, we presuppose the optimality of inducing cooperation. Nonetheless, we show that problems similar to the ones analyzed in Lazear (1989) exist even in the absence of RPE. We extend the analysis in another dimension by studying the issue of the optimal team size, and the interaction between team size and the optimal cooperation-inducing incentive scheme. Specifically, we show that due to risk-sharing considerations the principal resorts to a suboptimal team size.

A second strand of the literature, very relevant to our work, is that on career concerns commenced by Holmström (1982b). He argues that when the agents' innate abilities are

[5] Rank tournaments can be considered as special (typically suboptimal) relative performance evaluation schemes. They are particularly appealing in the case where good cardinal measures of an agent's performance are hard to get, and where hence the principal has to content herself with ordinal rankings (e.g., Lazear and Rosen (1981)).

not known but can be inferred by past performance, agents' behavior is also affected by incentives other than the ones that are under the principal's direct control. To the extent that an agent's reputation affects her future remuneration, this agent would try to influence her reputation accordingly. Holmström (1982b) postulates that the agent has bargaining power vis-à-vis the market. She can therefore benefit from an improvement on reputation. Hence, he concludes that career concerns provide positive incentives. Nonetheless, Meyer and Vickers (1997) have shown that when the agent has no bargaining power, the career concerns effect translates itself into a ratchet effect. By appearing to be of high innate ability, the agent creates higher expectations with respect to her performance, and hence the principal becomes more demanding.

There are a number of other interesting applications and extensions of the career concerns model. Gibbons and Murphy (1992) show that in designing the optimal explicit incentive scheme, the principal takes into account these implicit incentives and accordingly reduces the power of the explicit incentive she offers. In this way, the effect career concerns have on the agent's behavior are undone. In other words, explicit and implicit incentives are substitute instruments. Dewatripont, Jewitt, and Tirole (1999) show that the substitutability of the two instruments depends on the additive production technology considered by most of the literature (including our work). If ability and effort enter in a multiplicative fashion in production, explicit and implicit incentives may become complements. Ortega (1999) analyzes the allocation of power within a firm. Managers who have more power are also more visible to the outside world and have consequently an implicit incentive to work hard. By the same token, uneven allocation of authority distorts the incentives of less powerful managers. However, the positive incentive effects on more powerful managers outweigh the negative incentive effects on those managers with less power.

By focusing on career concerns in a team environment, we tackle the issue of an agent's behavior when she is capable of affecting her colleagues' reputation. Our result, that an agent has an implicit incentive to make her colleagues appear to be of low ability, highlights the fact that sabotage incentives analyzed by Lazear (1989) do not arise only when the principal employs an RPE scheme. We show that even if the explicit incentives designed by the principal actually reward agents for their colleagues' good performance, sabotage considerations arise because of ratchet-type implicit incentives.

3 Setup of the Model

The models presented are in the tradition of Holmström's (1982b) paper on career concerns. There is a principal, denoted by P, and N agents, denoted by $i \in I \equiv \{1, ..., N\}$. Time is discrete, indexed by $t = \{1, 2\}$. The number of periods a team is active is called the team's time horizon.

3.1 Production

Aggregate output in period t is defined as $Y^t = \Sigma_{i \in I} y_i^t$. There are two interpretations for Y^t. It can be considered as the output of a firm that only employs labor, for instance, a consulting or a law firm. Alternatively, it may represent a firm's "labor product", which is maximized by a principal who takes her firm's capital endowment as given in the short run.

Agent i's observable performance measure in period t can be understood as the extent to which she fulfills a task that is assigned to her by the principal; for instance, through a job description. Let this measurable output of team-member i be denoted by

$$y_i^t = \theta_i + \varepsilon_i^t + e_{ii}^t + h(N) \sum_{j \neq i} e_{ji}^t.$$

Output is the sum of four elements: First, there is the agent's innate ability, θ_i, which is assumed to be a realization of a normally distributed random variable with mean 0 and variance σ_θ^2, and which is independently and identically distributed (i.i.d.) across agents. This variable reflects the fact that the agent's ability is subject to some systemic variation, symmetrically unknown to everybody. The second element is the realization of some exogenous transitory shock, $\varepsilon_i^t \sim \mathcal{N}(0, \sigma_\varepsilon^2)$, each agent's talent is subject to. These shocks are assumed to be i.i.d. across periods and agents. We denote by $\Sigma^2 \equiv \sigma_\varepsilon^2 + \sigma_\theta^2$ the variance of the random elements of the production process. Third, the agent puts effort into her assignment, e_{ii}^t.

Besides these elements which originate from Holmström's (1982b) analysis, we consider a fourth element, $h(N) \sum_{j \neq i} e_{ji}^t$, which represents the total output effect of the support ("help") an agent receives from her colleagues. Other agents' help increase agent i's output in an additive way. The next subsection analyzes in detail the notion of teamwork we employ.

3.2 Teamwork

Our notion of teamwork is one in which agents reciprocally help each other in their tasks. This setup reflects what organization sociologists (e.g., Wagemann (1995)) call a "hybrid work design", i.e., an organization that combines elements of interdependent and independent work. An example of such design is a research team.[6]

The following two assumptions are intended to capture in simple terms the costs (Assumption 1) and benefits (Assumption 2) of teamwork.

Assumption 1 *Increasing team size reduces the output effect of colleagues' support at an increasing rate:* $1 > h(N) > 0$ *and it is strictly decreasing and log concave.*[7]

The term $h(N)$ represents the marginal rate of technical substitution of the agent's own effort with "help" effort, and it embodies the disadvantages of teamwork, notably the *costs* associated with coordination and communication.[8] A number of problems arise when people help each other. For instance, an agent who needs help has to identify the colleague who has the skills needed for the solution of the problem, and who currently has some spare time to help. Moreover, the problem must be explained; there may be misunderstandings in the definition of the problem or different approaches for its solution. Hence, it is assumed that the marginal rate of technical substitution between different types of effort is decreasing in the team size. Add, for instance, an additional agent to a team consisting of M incumbents. This leads to an increase in the number of communication channels by M, while the potential help of the additional agent is diluted by M. Coordination costs are hence convex, and since $h(N)$ is an inverse measure of these costs, it is assumed to be concave.[9]

Assumption 2 *Agent* i*'s total cost is* $C(e_i) = \sum_{j \in I} c(e_{ij}) = \sum_{j \in I} \frac{e_{ij}^2}{2}$, *where* e_i *denotes the vector of efforts agent* i *puts into her own assignment, and those of her colleagues.*

[6]It is also in line with the perception of management practitioners of factors which define a team and determines its size. For example, Steven Gross of the Hay Group, a consulting company, states that "team size is contingent on the number of employees whose activities are interdependent and who are mutually accountable to each other for the results." (Compensation and Benefits Review (1996)).

[7]An example of a function satisfying Assumption 1 is $h(N) = 1 - aN^2$ with $N \in [2, (1/a)^{1/2}]$ and sufficiently small a.

[8]The other potential disadvantage, free-riding, is mitigated, since the presence of the principal solves the budget-balanced problem. Moreover, the fact that different agents' efforts enter additively in the production function allows each agent to independently choose her efforts.

[9]Practitioners are aware of the exponential increase in coordination costs when team size increases (e.g., Fried (1991)).

The benefits of teamwork are modeled through the agents' cost function. Monotonous tasks are less pleasant, and consequently lead to quicker exhaustion than more variable tasks. Katzenbach and Smith (1993), for instance, phrase this as the "fun principle" of teamwork. In particular, they report that *"...we inevitably hear that the deepest, most satisfying source of enjoyment comes from 'having been part of something larger than myself' "* (page 19). The same authors attribute additional advantages of teamwork to complementarities in production, such as, complementary problem-solving, decision-making, technical, functional or interpersonal skills. Put differently, at a given team effort level, the team output is larger than the sum of individual outputs. Our setup can be understood as capturing these advantages as well, although in its inverted form. At a given agent's cost of effort level, more can be produced by this agent if she works on more than one task. Also in line with our setup are the empirical findings of Drago and Garvey (1996). In a study on the incentives to exert helping effort in workgroups, they found that task variety increases the willingness of people to help their colleagues.

Remark: It is usually assumed that a team is the smallest organizational unit, the performance of which is monitored by the principal.[10] Our framework, by highlighting the multitask character of teamwork, allows us to endogenize the principal's choice over the basic monitoring unit in her organization, and to show that generically the principal would strictly prefer to monitor individual performance.[11] We find that the only case in which the principal chooses, without loss of optimality, to ignore individual performance indices and to concentrate on an aggregate performance measure is when her agents' task assignment between "own" effort and "help" effort is trivial, in the sense that there is perfect principal-agent congruence. This occurs only in the limiting case when $h(N) = 1$. In all other cases, it is in the interest of the principal to engage in costly monitoring to acquire disaggregate information in order to induce optimal task assignment within a team.

3.3 Preferences

The risk-neutral principal maximizes output net of wages:

$$U_P = \sum_{t=1}^{2} \sum_{i \in I} [y_i^t - w_i^t].$$

[10]See, for example, Holmström (1982a).

[11]This is the case even though there are no free-riding incentives among team members.

Following the framework used in Holmström and Milgrom (1987, 1991), we assume that agent i is endowed with a constant absolute risk aversion (CARA) utility function:

$$U_i = -exp\left\{-r\sum_{t=1}^{2}[w_i^t - C(e_i^t)]\right\},$$

where r is the CARA coefficient. Notice that due to the multiplicative separability of the utility function, the agent does not value income smoothing across periods, i.e., the agent behaves as if she has access to perfect capital markets.

We assume that when the agent does not enter the labor market, she receives a payoff equal to her expected innate ability.[12] Given that the expected value of θ_i is normalized to 0, the agent's outside opportunity is also zero.

3.4 Teamwork Management

The principal utilizes two instruments for teamwork management. She chooses the size of the team (N), and the wage contracts she offers to her agents (w).

The goal of the principal is to choose the optimal N that maximizes the profits of the firm. Nonetheless, the principal does not need to constrain herself into forming only one team. She can, in principle, assign her agents to many different teams by breaking one large team into many smaller ones. Hence, the relevant objective she wants to maximize over in order to find the optimal team size is not the team expected profit, $E\Pi(N)$, but the per capita expected profit, $E\Pi(N)/N$.

In accordance with Holmström and Milgrom (1987), we concentrate on linear contracts. This allows us to build on previous work, most notably on Gibbons and Murphy (1992), and to compare our results with theirs. Hence, agent i's salary in period t is of the following form:

$$w_i^t = \sum_{j\in I}\alpha_{ij}^t y_j^t + \zeta_i^t,$$

where α_{ij} relates agent i's remuneration to agent j's output. The incentive component of the remuneration can be disentangled into an individual incentive component α_{ii}^t, and a collective incentive component α_{ij}^t, $\forall j \neq i$. Making use of the fact that the equilibrium is

[12] This could be, for instance, the case if the agent's alternative is to work in the informal sector, which is not subject to moral hazard.

symmetric, we can denote α_{ii} by α_{ind} and α_{ij} by α_{col}, $\forall\ i, j$. Hence, agent i's wage can be expressed as:

$$w_i^t = (\alpha_{ind}^t - \alpha_{col}^t) y_i^t + \alpha_{col}^t Y^t + \zeta_i^t. \tag{1}$$

3.5 First Best

In the first best world, the principal is able to observe her agents' effort levels. This allows her to offer contracts that specify effort assignments. Clearly, the optimal contract insures completely the agents, and requires the technologically efficient levels of effort, i.e., $e_{ii}^{fb} = 1$ and $e_{ij}^{fb} = h(N)$, $\forall\ i, j \neq i$.[13] To provide perfect insurance, the principal chooses $\alpha_{ii}^{fb} = \alpha_{ij}^{fb} = 0$, $\forall\ i, j$, and sets $\zeta_i^{fb} = C(e_i^{fb})$ in order to satisfy the agents' individual rationality constraints. Given the agents' utility function, the optimal contract is the repetition of the contract that is optimal in a static one-period framework.

Given the optimal contract, the per capita expected profits can be expressed as a function of the team size:

$$\frac{E\Pi(N)}{N} = \frac{1}{2} + (N-1)\frac{h(N)^2}{2}.$$

The optimal team size, denoted by N^{fb}, can be found by differentiating the per capita expected profit with respect to N. By Assumption 1, the following first order condition is also sufficient:

$$-\frac{h(N)}{h'(N)} = 2(N-1). \tag{2}$$

4 Full Commitment to Life-Time Salary Paths

We now consider the case in which the principal can commit to life-time salary paths. She offers to each agent a contract that specifies the first and the second period incentive schemes, i.e., $\{\alpha_i^t, \zeta_i^t\}_{t=1,2}$. Before analyzing the two-period model, we focus on a one-period model, which is used to get insights on the effects of changes on the team's time horizon.

[13] Throughout the paper, the index "fb" stands for "first best", and it is used when we want to denote the optimal value of a variable within the first best environment. Equivalently, the indices "st" (for "static" under moral hazard), "fc" (for "full commitment"), and "rp" (for "renegotiation-proof") are employed in the same fashion.

4.1 One-Period Model

When the principal cannot observe her agents' effort levels, she needs to give appropriate incentives to her agents to induce cooperation. Formally, the principal's problem can be represented by the following program:

$$\begin{aligned}
\max_{\alpha_i,\zeta_i} \quad & \sum_{i\in I} E[(1-\sum_{j\in I}\alpha_{ji})y_i - \zeta_i] \\
\text{s.t.} \quad & CE_i \equiv \sum_{j\in I}\alpha_{ij}Ey_j + \zeta_i - C(e_i) - \frac{r}{2}\sum_{j\in I}(\alpha_{ij})^2\Sigma^2 \geq 0, \quad \forall\, i, \qquad (IR_i) \\
& e_i \ \ argmax \ \ CE_i, \quad \forall\, i, \qquad (IC_i)
\end{aligned}$$

where

$$Ey_j = e_{jj} + h(N)\sum_{k\neq j} e_{kj},$$

and CE_i is the certainty equivalence of agent i's utility function. Each agent sets effort, such that $e_{ii}^{st} = \alpha_{ii}$, and $e_{ij}^{st} = h(N)\alpha_{ij}$, $\forall\, i, j \neq i$. Given the agents' behavior, the optimal contract offered by the principal is symmetric for all agents, and specifies:

$$\alpha_{ind}^{st} = \frac{1}{1+r\Sigma^2}, \tag{3}$$

$$\alpha_{col}^{st} = \frac{h(N)^2}{h(N)^2+r\Sigma^2}. \tag{4}$$

ζ^{st} is set such that the individual rationality constraints (IR_i's) are binding. Clearly, the incentive scheme is less powerful than the one necessary to induce the first best effort ($\alpha^{st} < 1$). The principal wants to insure her agents although this leads to underprovision of both the agent's own effort and help to others; a variation of the standard insurance versus incentives tradeoff.

Remark. Before moving to analyze the effect of the team size on the incentive schemes, we want to explain the importance of the helping technology specification we employ. We assume that agents are more productive when working on their own tasks than when helping others, i.e., $h(N) < 1$. If instead, we consider that there are no frictions in coordinating with other team members, i.e., $h(N) = 1$, (3) and (4) become identical. The fact that the agents are given the same individual and collective incentives implies that (1) collapses into $w_i^t = \alpha_{col}Y^t + \zeta_i^t$. It is important to notice that now the remuneration is a function of the total team output. No observation of individual performance is needed. Hence, it is the technological difference between working on one's own task and helping others that makes the agents' task assignment problem rich enough to require the principal to collect disaggregate information, and thus to invest in monitoring technology.

Having said that, we consider that Assumption 1 holds. One can derive some interesting comparative statics' with respect to the team size. The power of the per task collective incentive, derived in (4), is decreasing in the team size. The intuition is that as the team size increases, help becomes less productive, and hence, the principal's optimal reaction is to reduce the power of the collective incentives.

To be able to characterize the "cooperativeness" of the incentive schemes offered by the principal under the different environments, we define $\alpha_{col}/\alpha_{ind}$ as the collective orientation of the incentive scheme. The following proposition can be established by taking the respective derivatives with respect to N.

Proposition 1 *Ceteris paribus, smaller teams have more collectively oriented incentive schemes.*

We now turn to the characterization of the optimal team size. Conditional on the optimal incentive scheme, we can derive the optimal team size by maximizing with respect to N the per capita expected profit:

$$\frac{E\Pi(N)}{N} = \frac{\alpha_{ind}^{st}}{2} + (N-1)\frac{h(N)^2\alpha_{col}^{st}(N)}{2}.$$

Differentiating with respect to N, we get the following first order condition:

$$-\frac{h(N)}{h'(N)} = 2(N-1)\left(1+\frac{r\Sigma^2}{h(N)^2+r\Sigma^2}\right). \tag{5}$$

Clearly, unless agents are risk neutral ($r=0$), or there is no uncertainty in production ($\Sigma^2=0$), the right-hand side (RHS) of this first order condition is larger that the RHS of (2). Therefore, if we denote by N^{st} the solution to (5), and due to Assumption 1, it follows that $N^{st} < N^{fb}$.

Proposition 2 *(a) Unless there are no risk considerations, the optimal team size is smaller than in the first best. (b) The optimal team size is monotonically decreasing in the variance of the production process, and in the degree of risk aversion of its members.*

The intuition of this result is clear. The agents do not know the innate ability of their colleagues, and hence, the fact that their salary depends on all their colleagues' abilities imposes an additional risk they have to bear. The principal optimally shares part of the risk by reducing the power of the collective incentives (recall that α_{col}^{st} is decreasing in N). Nonetheless, this reduces the benefits of teamwork, and, as a result, the optimal team size shrinks.

4.2 Two-Period Model

We now allow the participants to be around for two periods. Formally, the problem facing the principal is the following:

$$\begin{array}{lll}
\max\limits_{\{\alpha_i^t\},\{\zeta_i^t\}} & \sum\limits_{t=1}^{2}\sum\limits_{i\in I} E[(1-\sum\limits_{j\in I}\alpha_{ji}^t)y_i^t - \zeta_i^t] & \\
s.t. & CE_i \equiv \sum\limits_{t=1}^{2}[\sum\limits_{j\in I}\alpha_{ij}^t E y_j^t + \zeta_i^t - C(e_i^t)] - \frac{r}{2}Var(w_i^1 + w_i^2) \geq 0, \quad \forall\, i, & (IR_i) \\
 & e_i^t \;\; argmax \;\; CE_i, \quad \forall\, i, t, & (IC_i)
\end{array}$$

where

$$Var(w_i^1 + w_i^2) = \sum_{j\in I}[(\alpha_{ij}^1 + \alpha_{ij}^2)^2\Sigma^2 - 2\alpha_{ij}^1\alpha_{ij}^2\sigma_\varepsilon^2].$$

The definition of the certainty equivalence involves a restriction on the remuneration contract. It specifies incentive schemes that depend only on the contemporaneous outcome; i.e., the second-period wage depends only on the second-period outcome. In our framework, this restriction is without loss of generality since utility is assumed to be multiplicatively separable across time.[14] Hence, agents do not value consumption smoothing. Moreover, since production is also separable across time, the principal cannot benefit by engaging in intertemporal risk-sharing.

One should however not confuse such long-term contract with two spot contracts. By committing herself to an expected second-period salary before she observes the first period outcome, the principal succeeds in insulating her agents' expected life-time income from the uncertainty they face with respect to the true ability of all team members— their expected life-time income does not depend on any of the actual θ_is.

Given that the agents face the same remuneration scheme in both periods, their problem is identical in both periods. They set their effort such that $e_{ii}^t = \alpha_{ii}^{t^{fc}}$, and $e_{ij}^{t^{fc}} = h(N)\alpha_{ij}^t$, $\forall\; i, j \neq i$ and t. Taking this behavior as given, the principal can solve for the optimal incentive scheme which is given by the following expressions:

$$\alpha_{ind}^{fc} \equiv \alpha_{ind}^{1^{fc}} = \alpha_{ind}^{2^{fc}} = \frac{1}{1 + r(\Sigma^2 + \sigma_\theta^2)}, \tag{6}$$

$$\alpha_{col}^{fc} \equiv \alpha_{col}^{1^{fc}} = \alpha_{col}^{2^{fc}} = \frac{h(N)^2}{h(N)^2 + r(\Sigma^2 + \sigma_\theta^2)}. \tag{7}$$

[14]When other utility functions were considered, such a restriction could not be imposed without loss of generality, cf. Harris and Holmström (1982).

The fixed components of the remuneration, $\zeta^{1^{fc}}$ and $\zeta^{2^{fc}}$, are set such that the individual rationality constraints (IR_i's) are binding.[15]

Comparing the optimal incentive scheme in the one- and two-period models (i.e., (6) and (7) with (3) and (4) respectively), one can see that α^{fc} is smaller than α^{st}. This result is very intuitive. An increase in the time horizon of the team increases the risk the agents bear with respect to the realization of their own and of their colleagues' innate abilities (i.e., the stakes of the gamble they face are larger). As a result, the principal has to lower the power of the incentive scheme to take into account her agents' intertemporal risk.

It is straightforward to show that the collective orientation of the incentive scheme is decreasing in the team size. It worth noting that this negative relationship between the collective orientation of the incentive scheme and the team size is stronger in the two-period than in the one-period model. Moreover, for a fixed N, the incentive scheme is more collectively oriented in the two-period than in the one-period model. These results are stated in the following proposition:

Proposition 3 *Ceteris paribus, teams with longer time horizons have (a) less powerful, and (b) less collectively oriented incentive schemes.*

We now turn to the characterization of the optimal team size. The per capita expected profit is given by the following expression:

$$\frac{E\Pi(N)}{N} = \alpha_{ind}^{fc}(N) + (N-1)h(N)^2\alpha_{col}^{fc}(N).$$

Differentiating with respect to N, we get the following first order condition:

$$-\frac{h(N)}{h'(N)} = 2(N-1)\left[1 + \frac{r(\Sigma^2+\sigma_\theta^2)}{h(N)^2 + r(\Sigma^2+\sigma_\theta^2)}\right]. \tag{8}$$

Comparing this first order condition with the one attained in the one-period model, one can see that the RHS in (8) is greater than the one in (5). This allows us to conclude that $N^{fc} < N^{st}$.

[15]It should be noted that $\zeta^{1^{fc}}$ and $\zeta^{2^{fc}}$ are indeterminate; only their sum is pinned down by the optimal contract. A straightforward, but interesting, implication of this feature is that the agents' right to quit in the middle of the relationship (i.e., after the first period) is not going to affect the optimal incentive scheme. The principal by setting a very low first period fixed salary and a very large second period's fixed salary can always ensure that her workers will not find it profitable to quit. The principal, in other words, due to her ability to commit, can costlessly buy out the workers' right to quit.

Proposition 4 *The optimal size of a team is inversely related to its time horizon.*

The intuition for this result is the following: The longer the team's time horizon, the larger the variations on an agent's life-time income which are due to the realizations of the innate abilities of her colleagues. This implies that the stakes of the gamble they face are larger. Hence, the risk the members of a team bear due to the inclusion of an additional member in the team becomes larger. To rebalance the trade-off between insurance and productive efficiency the principal decreases the size of the team.

5 Renegotiation-Proof Contracts

When the principal cannot commit herself to long-term incentive schemes, the analysis is equivalent to the one in which a new contract is offered every period.[16] This implies that when the second-period contract is being negotiated all involved parties have the ability to observe the first period's performance. Clearly, the second-period's contract will depend on this observation. Hence, the contracts offered by the principal are $\{\alpha_i^1, \zeta_i^1\}$ for the first period and $\{\alpha_i^2(y_1^1, y_{2,\ldots,}^1 y_{i,\ldots,}^1 y_N^1), \zeta_i^2(y_1^1, y_{2,\ldots,}^1 y_{i,\ldots,}^1 y_N^1)\}$ for the second.

5.1 Sabotage and Career Concerns

Suppose that at the end of the first period, the output of agent i is y_i^1, and that the conjectures about the first-period efforts that contributed to this output are $\widehat{e_{ii}^1}$ and $\widehat{e_{ji}^1}$, $\forall\, j \neq i$. In a rational expectations framework like ours, these conjectures are in equilibrium correct. Therefore, one can compute the conditional distribution of θ_i given the first-period output, which is normal with mean

$$\tilde{\theta}_i(y_i^1) = \frac{\sigma_\theta^2(y_i^1 - \widehat{e_{ii}^1} - h(N)\sum_{j\neq i}\widehat{e_{ji}^1})}{\sigma_\varepsilon^2 + \sigma_\theta^2},$$

and variance

$$\tilde{\sigma_\theta^2} = \frac{\sigma_\varepsilon^2 \sigma_\theta^2}{\sigma_\varepsilon^2 + \sigma_\theta^2}.$$

This implies that the variance of agent i's second-period output is going to be smaller. Both the principal and the agent have more precise predictions about the agent's ability. The second-period output variance is denoted by $\Sigma_1^2 \equiv \tilde{\sigma_\theta^2} + \sigma_\varepsilon^2$.

[16]For a demonstration of the equivalence, see Gibbons and Murphy (1992).

Each agent has the ability to take a report of her first-period output (which can be thought as her CV) to other prospective employers. Given the agent's report y_i^1, the principal offers to the agent a reputational bonus (which may be negative) equal to $\tilde{\theta}(y_i^1)$. Clearly, given the reputational bonus she has to offer, the principal is indifferent between employing a high reputation agent at a high salary or a low reputation agent at a low one. Moreover, the agent knows that she cannot get a better offer from any other firm.

This outcome can arise as the equilibrium of the following extensive form game. Each agent picks randomly a prospective principal and applies for a position. All prospective employees are queued and hold their reports. The principal, after observing the report of the first in line agent, makes an offer to her. If the offer is accepted, the agent is hired, otherwise she goes to another firm to ask for employment, and the principal starts bargaining with the next agent in line. Other papers in the literature (e.g., Holmström (1982b) and Gibbons and Murphy (1992)) assume that the agent has all the bargaining power during the renegotiation stage. In other words, the principal maximizes subject to a zero-profit constraint. Here in contrast, due to the multiagent framework, such formulation would be problematic. The bargaining process we envision succeeds in effectively making each agent the residual claimant only to her individual output.

The second period of the renegotiation-proof environment is isomorphic to the static environment analyzed in section 4.1. α_{ind}^{2rp} and α_{col}^{2rp} can be derived by replacing Σ^2 with Σ_1^2 in (3) and (4). In what follows we focus only on the novelties of this case.

The main difference is that now the outside opportunity for each agent is different depending on the reputational bonus she may claim. Hence, the second-period individual rationality constraint is the following:

$$CE_i^2(Y^1) \equiv E[w_i^2|Y^1] - C(e_i^2) - \frac{r}{2}Var[w_i^2|Y^1] \geq \tilde{\theta}(y_i^1).$$

Nonetheless, because of the additive technology, the incentive component of the contract is independent of the agent's reputation. The reasoning is that all agents, regardless of their true ability have the same marginal product of effort. This implies that only the fixed component of the salary depends on reputation. ζ_i^2 can be computed by solving the individual rationality constraint when binding:

$$\zeta_i^2(Y^1) = \tilde{\theta}(y_i^1) + C(e_i^2) + \frac{r}{2}\sum_{j\in I}(\alpha_{ij}^{2rp})^2\Sigma_1^2 - \sum_{j\in I}\alpha_{ij}^{2rp}E[y_j^2|y_j^1]. \tag{9}$$

When choosing her first-period effort level, each agent knows that this choice, besides affecting her first-period income ($w_i^1(e_i^1)$), affects, via her reputation, the fixed component of her second-period salary ($\zeta_i^2(e_i^1)$). Differentiating (9) with respect to the first-period effort, we can find the implicit incentives each agent considers, on top of the standard explicit incentives given by the principal via the first-period contract:

$$\begin{aligned}\frac{\partial \zeta_i^2(Y^1)}{\partial e_{ii}^1} &= (1-\alpha_{ind}^{2^{rp}})\frac{\sigma_\theta^2}{\Sigma^2},\\ \frac{\partial \zeta_i^2(Y^1)}{\partial e_{ij}^1} &= -\alpha_{col}^{2^{rp}}\frac{\sigma_\theta^2}{\Sigma^2}, \quad \forall\, j \neq i.\end{aligned}$$

The first equation shows the same *career concerns* effect, which is standard in the literature. By working more, an agent wants to increase her reputation, and hence to gain by the subsequent increase in her reputational bonus. However, this incentive is dampened by the fact that the second-period remuneration has an "incentive component". Because the agent is going to be perceived as more productive, the principal expects that the "incentive component" of the salary is going to be large, and hence, she increases the salary's "fixed component" by less than the increase in the reputational bonus.

The second equation conveys one of the main results of the paper, an implicit "ratchet" effect, which is manifested in the form of *sabotage*. When an agent helps her colleagues, she increases the output of her colleagues' assignments, which subsequently increases her colleagues' reputation. This increased reputation hurts the agent in question because it reduces her second-period fixed salary. The principal believes that this agent operates in a productive environment. This induces the principal to lower the fixed salary because she expects that the "collective incentive component" of the salary is going to be large. In other words, by helping her colleagues, an agent makes the environment she operates under look better without being able to capitalize on this enhanced perception.

This *sabotage* effect arises even though the explicit incentive scheme actually rewards agents for their colleagues' good performance. It is therefore, to the best of our knowledge, novel. It should be contrasted with the sabotage effect noted by Lazear (1989). There, sabotage arises because explicit incentives condition negatively the remuneration of one agent to her colleagues' performances. Neither it relies on any sort of implicit tournament. Our analysis hence brings forward a major difficulty in promoting teamwork. Unhindered cooperation can only be sustained in a high-commitment environment.[17]

[17] Extreme examples of the effect non-commitment has on employees' behavior can be traced in studies that relate organizational changes, such as downsizing or restructuring, to increased aggression among employees (e.g., Brockner et al (1992)). On the other hand, several studies on industrial relations in Japan have stressed the importance of "lifetime" employment security in the success of Japanese companies in promoting employees involvement in teamwork (e.g., Brown et al (1997)).

5.2 First-Period Contract

The principal's first-period profit maximization problem can be represented by the following program:

$$\begin{aligned}
\max_{\alpha_i^1,\zeta_i^1} \quad & \sum_{i\in I} E[(1-\sum_{j\in I}\alpha_{ji}^1)y_i^1 - \zeta_i^1] \\
\text{s.t.} \quad & CE_i \equiv \sum_{j\in I}\alpha_{ji}^1 E y_j^1 + \zeta_i^1 - C(e_i^1) + (SPNS) - \frac{r}{2}Var(w_i^1 + w_i^{2^{rp}}) \geq 0, \ \ \forall\, i, \qquad (IR_i) \\
& e_i^1 \ \ argmax \ \ CE_i \quad \forall\ i. \qquad (IC_i)
\end{aligned}$$

where $SPNS$ denotes the agent's expected second-period net surplus, which is

$$SPNS \ = \ \frac{r}{2}\sum_{j\in I}(\alpha_{ij}^{2^{rp}})^2\Sigma_1^2 + [E(\tilde{\theta}_i)],$$

and

$$Var(w_i^1 + w_i^{2^{rp}}) = \left((A_{ii}^1)^2 + \sum_{j\neq i}(A_{ij}^1)^2\right)\Sigma^2 + \sum_{j\in I}(\alpha_{ij}^{2^{rp}})^2\Sigma^2 + 2\left(A_{ii}^1\alpha_{ii}^{2^{rp}} + \sum_{j\neq i}A_{ij}^1\alpha_{ij}^{2^{rp}}\right)\sigma_\theta^2.$$

where $A_{ii}^1 = \alpha_{ii}^1 + (1-\alpha_{ii}^{2^{rp}})\frac{\sigma_\theta^2}{\Sigma^2}$ and $A_{ij}^1 = \alpha_{ij}^1 - \alpha_{ij}^{2^{rp}}\frac{\sigma_\theta^2}{\Sigma^2}$ are the effective incentives (i.e., the sum of the explicit and implicit incentives) the agents are influenced by.

This program has the following interpretation: Although the principal essentially offers a one-period contract, she takes into consideration the fact that in the next period the agent will be offered the contract which is optimal from the second-period's perspective. This second-period contract gives to the agent a net surplus (net of the cost of effort). Nonetheless, the principal benefits by offering a contract to the agent that insures her against the life-time risk she faces, while taking back in return the agent's second-period net surplus. The agent's life-time risk is represented by the variance of her life-time income $Var(w_i^1 + w_i^{2^{rp}})$.

The optimal incentive scheme is given in the following first order conditions:

$$\alpha_{ind}^{1^{rp}} \ = \ \frac{1}{1+r\Sigma^2} - (1-\alpha_{ind}^{2^{rp}})\frac{\sigma_\theta^2}{\Sigma^2} - \frac{r\alpha_{ind}^{2^{rp}}\sigma_\theta^2}{1+r\Sigma^2}, \qquad (10)$$

$$\alpha_{col}^{1^{rp}} \ = \ \frac{h(N)^2}{h(N)^2+r\Sigma^2} + \alpha_{col}^{2^{rp}}\frac{\sigma_\theta^2}{\Sigma^2} - \frac{r\alpha_{col}^{2^{rp}}\sigma_\theta^2}{h(N)^2+r\Sigma^2}. \qquad (11)$$

The optimal explicit incentive scheme has a very natural interpretation: The principal is fine-tuning the incentive scheme she offers in order to undo the effects of career concerns on her agents' decisions. This means that she reduces the power of the individual incentives and increases the power of the collective incentives.[18] The third ratio in both first order conditions expresses the principal's response on her agents' intertemporal risk, which arises from the fact that the agents will be members of the same team in the future. The principal reduces the power of the incentive scheme in order to share part of this risk.[19]

However, compared to the full commitment case, the principal cannot optimally spread now the intertemporal risk-sharing across both periods. The second period contracts have to be optimal from the second-period's perspective. As a result, from a risk-sharing perspective, the renegotiation-proof contract is worse than the full-commitment contract.

Comparing (10) and (11) with (6) and (7), we can track down the effect of commitment power on the character of the optimal explicit incentive schemes. There are two channels: First, the principal's retreat from her commitment to life-time salary paths creates implicit incentives. Given that in response to the presence of implicit incentives, the principal decreases the power of the individualistic incentives and increases the power of the collective incentives, we should expect that the orientation of the incentive scheme should be more collective under the renegotiation-proof regime. Second, the principal's inability to commit to a second-period salary that is not renegotiation-proof, severs her ability to shield her agents from their intertemporal human capital risk, and moreover, to allocate efficiently their life-time income risk across the two periods. The following proposition summarizes the discussion:

Proposition 5 *Ceteris paribus, the renegotiation-proof first-period incentive scheme is more collectively oriented compared to the one under full commitment.*

5.3 Optimal Team Size

To characterize the optimal team size in the renegotiation-proof environment one has to solve sequentially for the team size that maximizes the principal's per capita expected

[18]The fact that implicit and explicit incentives are substitutes depends on the additive-normal framework we have adopted. Dewatripont, Jewitt, and Tirole (1997) have shown that when ability and effort enter multiplicatively in the production function, explicit and implicit incentives can be complements.

[19]It is actually possible that the intertemporal risk bore by the agents is so large that there is a corner solution in the agents' effort decision, i.e., the principal induces zero effort. A sufficient condition for an interior solution is that $\sigma_\varepsilon^2 \geq \sqrt{3}\sigma_\theta^2$. This condition ensures that the principal does not learn too much about the agent's innate ability from the first-period output, and hence that the second-period contract is not going to be very powerful. An interesting implication of this is that no teamwork can be supported in the first period if the principal learns 'too' fast.

profits in each period.

Starting backwards, we first solve for the second-period optimal team size. Clearly, the problem faced by the principal is identical to the one analyzed in the one-period model. The only difference now is that the variance of the production is smaller due to the fact that the principal has learnt something about the agents' innate ability by observing the first-period output. Hence, the FOC for the determination of $N^{2^{rp}}$ can be derived by just replacing Σ^2 with Σ_1^2 in (5). It is straightforward to see that $N^{2^{rp}} > N^{st} > N^{fc}$.

When solving for the optimal first-period team size, the principal takes as given the composition of the team in the second period. The first period expected profit can then be written as a function of the optimal incentive schemes and of the second-period's team size:

$$\frac{E\Pi^1(N^1)}{N^1} = constant + (N^1 - 1)\left[\frac{h(N^1)^2 A^1_{col}(N^1)}{2} - \frac{r\sigma_\theta^2 \alpha_{col}^{2^{rp}}(N^{2^{rp}})\alpha_{col}^{1^{rp}}(N^1)}{2}\right].$$

Differentiating with respect to N^1, we get the following first order condition:

$$-\frac{h(N^1)}{h'(N^1)} = 2(N^1 - 1)\left(1 + \frac{\alpha_{col}^{2^{rp}} r\sigma_\theta^2 (2 + \alpha_{col}^{2^{rp}} \frac{\sigma_\theta^2}{\Sigma^2})}{h(N^1)^2 - \alpha_{col}^{2^{rp}} r\sigma_\theta^2(2 + \alpha_{col}^{2^{rp}} \frac{\sigma_\theta^2}{\Sigma^2})} + \frac{r\Sigma^2}{h(N^1)^2 + r\Sigma^2}\right). \quad (12)$$

After some tedious computations one can show that if the second-period increase in the size of the team is not too large that second-period incentives get diluted, then $N^{1^{rp}} < N^{fc}$.

Proposition 6 *If $h(N^{fb}) > \sqrt{\frac{\sigma_\varepsilon^2}{\Sigma^2}}$, then the optimal team size shrinks when the manager cannot commit to long-term contracts.*

Proof: See the appendix.

The intuition behind the result is clear. The fact that teamwork management decisions have to be renegotiation-proof severs the ability of the principal to allocate the risk her agents are bearing efficiently across periods. Second-period policies are chosen after the principal has observed the first-period output realization, and has consequently learnt more about her agents' innate ability. Due to the reduced uncertainty agents bear less risk in the second period. This induces the principal to offer more powerful incentive schemes, as well as to assemble larger teams than otherwise. As a result, the risk the agents bear from the first-period point of view gets exacerbated. To restore optimal risk-sharing, the principal has to take this fact into account and to attempt to reduce the risk borne by her agents by reducing the size of the team in the first period.

6 Further Implications

All preceding analysis has implicitly assumed that agents differ only with respect to their innate ability. Clearly though, employees differ from each other in many aspects. In this section we address two possible aspects in an employee's profile that could affect our analysis. First, labor markets are usually segmented (cf. Doeringer and Piore (1971)): There are employees who participate in a firm's internal labor market and see their employment in this firm as life-time career as well as those who mainly participate in the external labor market and whose tenure in firms tends to be short. Second, all employees in a firm do not have the same seniority: There are employees with long history, whose past performance has produced evidence of their ability as well as new-comers who have little to back their reputations.

6.1 Long-Term vs Temporary Workers

When analyzing the renegotiation-proof case, we considered that the principal keeps the same agents in both periods. We now turn our attention to the case in which the principal hires her agents on a temporary basis. That is, the agents know that in the second period they will be members of another team in another firm.

This change does not affect the analysis of the agents' incentives to provide their own effort. A good reputation affects the reputational bonus they will be able to secure, no matter in which firm they will end up being employed. This is not the case when one considers the agents' incentives to help their colleagues. Given that the first-period colleagues are not going to be the same with the second-period ones, an agent does not have to take any implicit incentives under consideration. She does not even know tomorrow's colleagues, let alone influencing their reputations. This means that the sabotage effect disappears in the case of temporary workers.

As a result, the collective first-period explicit incentive offered to temporary workers is different:

$$\alpha_{col}^{1^{temp}} = \frac{h(N)^2}{h(N)^2 + r\Sigma^2}.$$

Comparing this expression to the collective incentives given to a long-term worker, we see that the last two terms of the long-term worker incentives are missing. First, as already explained, there is no sabotage effect to take into consideration, and moreover, the temporary worker does not bear any intertemporal risk with respect to her colleagues' human capital (i.e., she draws a new set of colleagues every period). The following proposition compares the contracts given to the two types of workers.

Proposition 7 *The incentive scheme given to temporary workers is more individually oriented compared to the one given to long-term workers.*

This result highlights the fact that there are differences between internal and external labor markets even when both share the same information.

6.2 Junior vs Senior Teams

Labelling first-period workers "junior" and second-period workers "senior" recruits, we can compare the incentive schemes given to each type of workers by a short-lived principal, as well as the optimal team size in each case.

For the analysis one has just to observe that the variance of the output produced by an agent is equal to Σ^2 in the first case, and Σ_1^2 in the second case. Since, $\Sigma^2 > \Sigma_1^2$, there is more of an uncertainty in junior teams than is senior teams. From Proposition 1 we know that the individual orientation of the incentive schemes becomes stronger in the variance of the production, and from Proposition 2 that the optimal team size decreases. A straightforward implication of these results on the differences between junior and senior teams is presented in the following proposition.

Proposition 8 *(a) Senior agents are offered more collectively oriented incentive schemes; and (b) teams that consist of senior members are larger.*

7 Conclusions

This paper shows that the presence of implicit incentives makes the agents more reluctant to behave cooperatively (they actually have incentives to "sabotage" their colleagues). This forces the principal to offer more "collectively oriented" incentive schemes than when the principal has the ability to commit herself to salry paths in order to induce the desired level of cooperation. Moreover, it is demonstrated that teamwork exposes agents to higher risks than the ones they are exposed to in a workplace based on individual production. Hence, the optimal team size is constrained by risk considerations. It is decreasing in the uncertainty of the production technology and in the team's time horizon. Finally, teams in environments where managers have less commitment are smaller than teams the managers of which are able to make long-term commitments.

Our paper highlights the effects that exogenous factors have on the efficacy of human resource practices. Notice that the environment that we consider is one in which turbulences are not even very dramatic: in particular, workers do not face income risks when fired. Nevertheless, the fact of diminishing commitment affects the workplace substantially, and the firm has to intensify its efforts to induce workers' cooperation. Clearly, considering more severe risks than the loss of wage security may enforce our predictions. This and the endogenization of the loss of managerial commitment due to changes in product and financial markets appear fruitful avenues for further research.

As it stands, our prediction that diminished managerial commitment induces firms to increasingly rely on collective incentive schemes is in line with what human resource specialists believe the workplace of the future will look like. Dyer and Blancero (1993), for instance, report the opinions of 57 human resource executives, consultants, and academics who claimed that, "in the future, variable pay will be based to a lesser degree on individual performance and to a much greater degree on firm, business-unit and work-unit performance."

Bibliography

Bertrand, M., (1998) “From the Invisible Handshake to the Invisible Hand? How Product Market Competition Changes the Employment Relationship”, mimeo.

Brockner, J., S. Grover, T. Reed and R.L. Dewitt, (1992) “Layoffs, Job Insecurity, and Survivors’ Work Effort: Evidence of an Inverted-U Relationship”, *Academy of Management Journal* 35: 413-425.

Brown, C., Y. Nakata, M. Reich and L. Ulman, (1997) *Work and Pay in the United States and Japan*, New York: Oxford University Press.

Compensation and Benefits Review, (1996) “The Network Discusses: Team Size, Pay, Performance, and Awards”, 28: 16-17.

Dewatripont, M., I. Jewitt and J. Tirole, (1999) “The Economics of Career Concerns, Part I: Comparing Information Structures”, *Review of Economic Studies* 66: 183-198.

Doeringer, P. and M. Piore, (1971) *Internal Labor Markets and Manpower Analysis*, Lexington MA: Heath.

Drago, R. and G. Garvey, (1996) ”Incentives for Helping on the Job”, mimeo.

Dyer, L. and D. Blancero, (1993) ”Workplace 2000: A Delphi Study”, WP Cornell, quoted in Gerhart, B., H. Minkoff and R. Olsen (1995): ”Employee Compensation: Theory, Practice and Evidence” in Ferris, G., Rosen, S. and D. Barnum: *Handbook of Human Resource Management*, Blackwell Business, Cambridge Mass.

Farber, H., (1997) ”The Changing Face of Job Loss in the United States, 1981-1995”, *Brookings Papers on Economic Activity*: 35-128.

Fried, L., (1991), “Team Size and Productivity in Systems Development”, *Information Systems Management* 8: 27-35.

Gibbons, R. and K. Murphy, (1992) “Optimal Incentive Contracts in the Presence of Career Concerns: Theory and Evidence”, *Journal of Political Economy* 100: 468-505.

Harris, M. and B. Holmström, (1982) “ A Theory of Wage Dynamics”, *Review of Economic Studies* 49: 315-334.

Holmström, B., (1982a) "Moral Hazard in Teams", *Bell Journal of Economics* 13: 324-340.

Holmström, B., (1982b) "Managerial Incentive Problems — A Dynamic Perspective", *in Essays in Economics and Management in Honour of Lars Wahlbeck*, Helsinki: Swedish School of Economics; also in *Review of Economic Studies* 66: 183-198.

Holmström, B. and P. Milgrom, (1987) "Aggregation and Linearity in the Provision of Intertemporal Incentives", *Econometrica* 55: 303-328.

Holmström, B. and P. Milgrom, (1990) "Regulating Trade among Agents", *Journal of Institutional and Theoretical Economics* 146: 85-105.

Holmström, B. and P. Milgrom, (1991) "Multi-Task Principal-Agent Analyses: Incentive Contracts, Asset Ownership, and Job Design", *Journal of Law, Economics, and Organization* 7 Sp.: 24-52.

Ichniowski, C., K. Shaw and G. Prennushi, (1997) "The Effects of Human Resource Management Practices on Productivity: A Study of Steel Finishing Lines", *American Economic Review* 87: 291-313.

Itoh, H., (1991) "Incentives to Help in Multi-Agent Situations", *Econometrica* 59: 611-636.

Itoh, H., (1992) "Cooperation in Hierarchical Organizations: An Incentive Perspective", *Journal of Law, Economics, and Organization* 8: 321-345.

Kanter, R., (1992) *When Giants Learn to Dance*, London and New York: Routledge.

Katzenbach, J. and D. Smith, (1993) *The Wisdom of Teams*, Boston: Harvard Business School Press.

Lawler, E., S. Mohrman and G. Ledford, (1995) *Creating High Performance Organizations*, San Francisco: Jossey Bass Publishers.

Lazear, E., (1989) "Pay Equality and Industrial Politics", *Journal of Political Economy* 97: 561-580.

Lazear, E. and S. Rosen, (1981) "Rank-Order Tournaments as Optimum Labor Contracts", *Journal of Political Economy* 89: 841-864.

Locke, R., T. Kochan and M. Piore (eds), (1995) *Employment Relations in a Changing World Economy*, Cambridge: MIT Press.

Mc Shulskis, E., (1997) “Rebuilding Employees’ Trust”, *Human Resources Magazine* 42, no.10: 22.

Meyer, M. and J. Vickers, (1997) “Performance Comparisons and Dynamic Incentives”, *Journal of Political Economy* 105: 547-581.

Mookherjee, D., (1984) “Optimal Incentive Schemes with Many Agents”, *Review of Economic Studies* 51: 433-446.

Ortega, J. (1999), ”Power in the Firm and Managerial Career Concerns”, mimeo.

Robinson, S. (1996), ”Trust and Breach of The Psychological Contract”, *Administrative Science Quarterly* 41: 574-600.

Wagemann, R., (1995) “Interdependence and Group Effectiveness”, *Administrative Science Quarterly* 40: 145-181.

Appendix

Proof of Proposition 6: One can rewrite (12) as

$$-\frac{h(N^1)}{h'(N^1)} = 2(N^1-1)\left(1+\frac{r\Sigma^2+r\sigma_\theta^2\alpha_{col}^{2^{rp}}}{h(N^1)^2+r\Sigma^2}\right)\times\frac{h(N^1)^2-r\sigma_\theta^2\alpha_{col}^{2^{rp}}}{h(N^1)^2-2r\sigma_\theta^2\alpha_{col}^{2^{rp}}-r\sigma_\theta^2(\alpha_{col}^{2^{rp}})^2\frac{\sigma_\theta^2}{\Sigma^2}}.$$

Note that the rightmost ratio is greater than 1. Therefore, to see if $N^{1^{rp}} \leq N^{fc}$ it is sufficient to see if it is true that

$$\frac{r\Sigma^2+r\sigma_\theta^2\alpha_{col}^{2^{rp}}}{h(N^1)^2+r\Sigma^2} \geq \frac{r(\Sigma^2+\sigma_\theta^2)}{h(N^1)^2+r(\Sigma^2+\sigma_\theta^2)}.$$

This condition is equivalent to $\alpha_{col}^{2^{rp}} \geq \frac{h(N^1)^2}{h(N^1)^2+r(\Sigma^2+\sigma_\theta^2)}$. By taking $h(N^1)^2=1$ and replacing $\alpha_{col}^{2^{rp}}$ with its optimal value, the condition above is implied by $\frac{h(N^{2^{rp}})^2}{h(N^{2^{rp}})^2+r\Sigma_1^2} \geq \frac{1}{1+r(\Sigma^2+\sigma_\theta^2)}$, which in turn, is equivalent to $h(N^{2^{rp}})^2 \geq \frac{\sigma_\varepsilon^2}{\Sigma^2}$. Finally, by Proposition 2, this condition is implied by $h(N^{fb})^2 \geq \frac{\sigma_\varepsilon^2}{\Sigma^2}$. Q.E.D.