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LIMITED INTERTEMPORAL COMMITMENT AND JOB DESIGN

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Abstract

Should workers be given jobs where they have joint responsibility for tasks, or should tasks be separated into different jobs with individual responsibility? Or, if there are more tasks than workers, how should tasks optimally be grouped together? And to what extent should workers be allowed to pursue outside activities while they are at work? Recent work has demonstrated that when the various tasks are substitutes for the worker, static incentive considerations yield the following answers: Separate tasks, and if that is not possible, group together tasks with the same possibility of performance evaluation. Moreover, workers should be given more discretion to pursue outside activities the easier it is to measure their performance on the workplace activity. We show that if a principal who faces an intertemporal commitment problem in her motivation of workers follows these advices, then the negative consequences of the commitment problem are reinforced. More generally, we inquire about optimal job design in an intertemporal agency model, and we find that the answers may be quite different from those obtained on the basis of a static model.

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1 Introduction.

Recent economics literature has made it clear that there are strong links between job design and incentives. The design may affect the measurements that are available as indicators of performance, and which therefore can be used as a basis for incentive payments. It also affects the set of tasks that each agent is supposed to work on. For jobs that involve multitask assignments, the compensation system not only serves the dual function of motivating productive work and allocating risks. In addition it serves as a mechanism for allocating the agent's attention between the different assignments. A principal that tries to motivate an agent by offering incentive pay for tasks where performance related measurements are available, may draw the agent's attention away from tasks where performance is harder to measure and where incentive pay cannot be used[1]. Job design is an instrument the principal can use to affect this tension between work motivation on individual tasks and attention allocation between tasks. A number of recent papers, including Holmstrom and Milgrom [1991] and Itoh [1992], discuss how this insight affects conclusions about how performance incentives should be used to compensate agents, and how the multitask problem can shed light on issues related to job design.

Among others, the following three issues have been put on the agenda. Task sharing: Should workers be given jobs where they have joint responsibility for tasks, or should tasks be separated into different jobs with individual responsibility? Task grouping: If there are more tasks than workers, what is the best way for the principal to group them together? Outside activities: To what extent shall workers be allowed to spend time and energy on private projects (on outside activities) while they are at work? The analytical framework used to study these job design questions has been a one shot principal-agent relationship. It is important to investigate the robustness of the results that are derived in

[1]Different "tasks" could be interpreted as different attributes of a product produced by the agent, as for example output and quality. In many cases it is then reasonable to assume that output, but not quality, is measurable, see Laffont and Tirole [1993] and the references therein. If the agent's wage is based on quantity this may make him concentrate on output and pay less attention to quality.

this framework. The purpose of this paper is to examine whether some of the conclusions regarding optimal compensation and job design change when we moderate the assumption of complete intertemporal commitment. To give an idea of how a lack of intertemporal commitment affects the analysis of optimal job design, it is instructive to consider the task sharing problem mentioned above.

In a one shot or static model there is a strong incentive based argument in favor of designing jobs so that workers get separate responsibility for tasks. This occurs whenever the agent regards efforts spent on the various tasks as substitutes. To illustrate, consider the case of perfect substitutability, i.e., where the agent's marginal disutility of supplying an extra unit of effort is independent of which task he allocates the unit to. An agent will then work on two tasks only if they give him the same compensation on the margin. A principal that wants an agent to allocate adequate amounts of time and effort on two tasks must therefore provide incentives with the same degree of power on both tasks. Suppose further that the measurement errors for the two tasks are stochastically independent. If we then compare two alternative job arrangements, one in which workers have joint responsibility for tasks and one with individual responsibility, and we require the total amount of effort supplied to each task to be the same in both cases, it is clear that joint responsibility leads to a higher overall income variance for the agents.[2] Risk averse agents will require a compensation for increased risk exposure, and this makes it relatively costly to use high powered incentives to motivate efficient effort supply when agents are jointly responsible for tasks. A competent principal will therefore separate the tasks[3].

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[2] The aggregate level of effort supplied to each task will be invariant to a change in job arrangements if, and only if, the incentive wage offered for each task is invariant to such a change. For a given effort choice it is clear that the variance in the agent's income increases with the number of sources (tasks) from which the agent collects his income.

[3] The principal may still choose to offer integrated jobs if there is complementary between the different tasks, so that working on one makes it easier to undertake another task. Notwithstanding, holding these other rather obvious arguments in favour of multitask jobs constant, work motivation and the problem of observing performance draws in the direction of offering single task jobs, or of grouping together tasks that have approximately the same possibility of performance evaluation.

The reason we find it interesting to study the multitask problem and optimal job design in a dynamic framework, is the observation that "low powered" compensation schemes has a positive effect if the principal and the agent cannot write complete long term contracts: It alleviates the ratchet effect. This dynamic incentive effect makes the analysis of job design more subtle, and in some cases the principles for optimal job design turn out to be exactly the opposite of what they are in a static setting.

To illustrate how a lack of intertemporal commitment affects the principles for optimal job design, we must first explain why low powered incentives can be beneficial in a dynamic model. Consider a situation where the principal bases her compensation rule on inaccurate signals of the agents' performance. Assume that the measurements of each agent's performance are correlated over time, e.g. because they reflect a stationary intrinsic ability on the part of the agent. If long term commitments cannot be made, each agent knows that superior performance now reveals information which will, for a given choice of effort, reduce future compensation. This connection between good performance today and the ratcheting up of future performance targets makes the agent unwilling to perform efficiently early in the relationship (Weitzman, 1976). Low powered incentives in the future is then an advantage since it reduces the importance of the ratchet effect by making the agent's future compensation less dependent on his own effort choice. The agent's private gain if he behaves strategically and work with low effort early on, is therefore reduced if he in the future will be offered a compensation scheme which is only moderately based on measured performance.

Consider again the task assignment problem. The implication of the argument above is that a change in the organisation structure from one that offers multitask jobs, to one where each worker is made responsible for a single task, has a negative intertemporal effect. Individual responsibility leads to high powered incentives, and the agent has much to gain by behaving inefficiently in early periods. With joint responsibility of tasks, incentives are low powered and the gain of behaving inefficiently in early periods is lower. Principals that presently offer multitask jobs will, from the static analysis of the multitask problem, get the impression that they could be made better off if they restructure the present organisation and change it to one where workers are given single task jobs. We tell these principals that there is another effect they must consider before they decide to do so. If they face an intertemporal commitment problem in their regulation of agents, they should beware that the negative consequences of this commitment problem are reinforced if they choose single task jobs. The situation is therefore more delicate now. There is a trade off between offering mixed or single task jobs. It is this trade off we will study in a formal model. After the discussion of the task separation problem we extend the model to study how the dynamics and the ratchet problem influences the optimal regulation of agents' possibilities to work on outside activities.

A standard reference on incentive issues in job design is Holmstrøm and Milgrom [1991]. Related issues are considered by Itoh [1991, 1992] and by Laffont and Tirole [1993]. The latter paper takes an adverse selection approach, the others take a moral hazard perspective. Some implications of limited commitments and ratcheting for organization design have been explored recently, see Martimort [1993] and Olsen and Torsvik [1992, 1993a,b] for analyses pertaining to common agency structures and to collusion phenomena--all in adverse selection models--and Meyer [1994], Meyer and Vickers [1994] for analyses of cooperation and comparative performance evaluation in models with moral hazard. In the following analysis of task assignment and regulation of outside activities we use a model based on that one developed by Meyer and Vickers.

2 The task assignment problem.

In our intertemporal model there are two agents, two tasks to be done, and the agents work for the principal for two periods. We will, however, first outline the static problem[4].

The task separation problem in a static framework.

The agents denoted i and j are identical, so what we say about agent i holds true for agent j as well. The agent makes an effort choice (e_i, e_i'), where e_i is the effort he supplies to one of the tasks and e_i' is the effort supplied to the other. The private cost, measured in monetary units, for the agent if he supplies (e_i, e_i') is $C(e_i + e_i')$. Thus, the agent considers the two different tasks as perfect substitutes. Furthermore we will assume that the cost function is quadratic, $C(e_i + e_i') = (1/2)(e_i + e_i')^2$.

Given the effort chosen by both agents the principal receives an expected gross benefit of $B(e_i + e_j)$ + $B(e_i' + e_j')$. The agents' choice of effort also generates information signals $x = (e_i + e_j) + u$ and $x' = (e_i' + e_j') + u'$. The stochastic terms u and u' are assumed to be independent and normally distributed, both with zero mean and with variances v and v', respectively.

The principal offers each agent a linear compensation rule[5]. The agent's wage is therefore $l_i = \alpha_i + \beta_i x + \beta_i' x'$ and the expected income for agent i is $El_i = \alpha_i + \beta_i(e_i + e_j) + \beta_i'(e_i' + e_j')$.

The agent's utility function is exponential, $u(y) = -\exp(-ry)$, where $y = l_i - C(e_i + e'_i)$. With linear incentives and exponential utility we can write the agent's certainty equivalent as $CE_i = El_i - C(e_i + e_i') - (r/2)\operatorname{var}(l_i)$.

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[4]In this case the model is a special version of the Holmstrom-Milgrom [1991] multitask model.
[5]This static model can be "embedded" in a larger model where linear incentive schemes are optimal, see Holmstrom and Milgrom [1987].

Consider the case where both tasks are shared, so the agents have joint responsibility for both tasks. It is clear that in order to induce positive efforts on both tasks ($e_i > 0$ and $e_i' > 0$) we must have $\beta_i = \beta_i'$. For symmetric agents we will further have $\beta_i = \beta_j = \beta$. The agent's certainty equivalent is then

$$CE_i = \alpha_i + \beta(e_i + e_j + e'_i + e'_j) - C(e_i + e'_i) - \frac{1}{2} r\beta^2 (v + v').$$

The principal is risk neutral, her expected profit is $B(e_i + e_j) + B(e'_i + e'_j) - El_i - El_j$. The benefit function *B*() is assumed to be concave. The total certainty equivalent, the agents' and the principal's joint surplus, is given by

$$TCE = B(e_i + e_j) + B(e'_i + e'_j) - C(e_i + e'_i) - C(e_j + e'_j) - r\beta^2 (v + v').$$

A Pareto efficient incentive contract maximises *TCE*. The principal's maximisation problem must be done subject to the constraints that the agents will choose effort optimally given the incentive wages they are offered. These constraints are given by,

$$\beta = C'(e_i + e'_i) = e_i + e'_i$$
$$\beta = C'(e_j + e'_j) = e_j + e'_j.$$

By assumption the principal's gross benefit functions are identical across the two tasks. If both agents work on both tasks, it is advantageous for the principal that effort is equally distributed between the two tasks. The agents are willing to supply their effort in this manner since there is perfect substitutability in effort supply, so we may set $e_i = e_j$ and $e'_i = e'_j$. Since by symmetry the agents then contribute equally to the principal's profit, we can write the principal's maximisation problem as;

$$\underset{\beta}{Maximize}\colon\ 2\left\{B(\beta) - C(\beta) - \frac{1}{2} r\beta^2 (v + v')\right\}.$$

Consider next a single agent working on a single task. Let w denote the maximal value of his contribution and v the total variance in the information signals the principal receives about his effort. We can then write;

$$(1) \qquad w(\nu) = \max_{\beta}\left[B(\beta) - C(\beta) - \frac{1}{2}r\beta^2\nu\right].$$

Let $\beta = \beta(\nu)$ be the optimal bonus in (1). We can see from the third term in the maximum value function that a higher ν will reduce optimal incentives; $\partial\beta / \partial\nu < 0$. A higher variance in the information signal will thus lead to more low powered incentives. It is also straightforward to see that $\frac{\partial w}{\partial \nu} = -\frac{1}{2}r(\beta)^2 < 0.$ Based on this we can make the following statement (which is an adaptation of Holmstrom and Milgrom's results about task sharing to a two tasks two agents setting, see Proposition 5 in Holmstrom and Milgrom [1991]):

Proposition 1. In the static version of the model outlined above, where the principal has two tasks that must be done and two agents at disposition, it is optimal to offer each of them jobs in which they get individual responsibility for each task.

Proof: The proof is simple. With joint responsibility the principal's profit is $2w(v+v')$. With separated tasks each agent alone is responsible for a task, and the principal's profit is $w(v)+w(v')$. And $\frac{\partial w}{\partial \nu} < 0$ implies $2w(v+v') < w(v)+w(v')$. □

The task separation problem in a dynamic framework.

In the dynamic problem the principal hires the agents for two periods. She cannot ex ante fully commit herself to a future (second period) compensation scheme. We assume that the error terms in the measurements of the agents' efforts are positively correlated over time. The principal must therefore deal with a ratchet problem[6]. We study how the ratchet effect influences optimal job design. Our results can then be viewed either as a straightforward comparison of how different job arrangements perform in organizations which face dynamic agency problems, or alternatively it can be viewed as a normative

[6]The two period model we use here is developed by Margaret Meyer and John Vickers [1994], see also Meyer [1994]. In these papers it is discussed how implicit mechanisms, like the the ratchet effect and career considerations, influence the design of compensation schemes based on comparative performance evaluation.

study on optimal job design. In the latter case it must be assumed that it is costly to make frequent changes in the organization of production, and that the principal therefore ex-ante can commit to a future job design. This seems to be a resonable assumption in many cases. Another argument is that the nature of some jobs or manufacturing processes makes it difficult to separate different tasks. For example, in many situations it will be very difficult or maybe impossible to separate the task of providing quality from the task of providing quantity. Static incentive considerations indicate that even if the nature of some tasks makes it very costly to separate them from others, it may still be worth doing so. If the same problem is studied in a context with limited intertemporal commitment one sees that, with respect to job design, dynamic incentive effects draw in the direction of job sharing. In this situation our analysis clearly function as a normative study of job design.

We will assume that the agents work for the principal in both periods. An agent chooses therefore effort in the first period based on the prospect that he will work for the principal also in the second period. There are several ways to justify this assumption. They all boil down to pointing at reasons why it is costly for the agent to leave the relationship. The agent may have to pay a penalty if he leaves. Alternatively the salary for the first period can be made contingent on participation in the second period. The latter alternative requires that the principal can make a limited commitment. Indeed, the intertemporal contract we characterize is the optimal (linear) contract for a case where the parties (or at least the principal) can commit to a long term contract, but where they cannot commit not to renegotiate (see also Meyer 1994).

One agent and one task.

Consider first the single agent /single task problem. The principal is risk neutral. Her intertemporal payoff is $B(e_1) - El_1 + B(e_2) - El_2$, where l_t is the wage payment and e_t is the agent´s effort in period t. The agent has intertemporal utility

$-\exp\{-r[l_1 - C_1 + l_2 - C_2]\}$, where $C_t = C(e_t)$ is the effort cost in period t. The information signal in period t is given by, $x_t = e_t + u_t$. The error terms are normally distributed with zero mean and variance v. Correlation over time is positive; $\mathrm{corr}(u_1, u_2) = \gamma > 0$. The second period conditional variance of the error term is therefore $v_2 = \mathrm{var}(x_2|x_1) = (1-\gamma^2)v$. A positive correlation means that the agent's first period behaviour has implications for the contract he is offered in the second period.

Given that the principal can make a limited commitment, she initially offers a long-term contract $(\alpha_t, \beta_t), t = 1,2,$ where α_t is the fixed payment and β_t is the incentive bonus in period t. (So the agent's payment in period t is $l_t = \alpha_t + \beta_t x_t$.) The second-period contract generally depends on the observed outcome x_1 from period 1. We may assume that the second-period bonus is equal to the optimal incentive bonus in period 2, conditional on the observed first-period outcome. (Otherwise it would be renegotiated to this value.) This optimal bonus happens to be independent of x_1; it depends only on the conditional second-period variance v_2, i.e., $\beta_2 = \beta_2(v_2)$--see (1). For an effort e_2, the agent's expected second period compensation, conditional on the first-period outcome, is then $E(l_2|x_1) = \alpha_2 + \beta_2[e_2 + \gamma(x_1 - \hat{e}_1)]$. Here $\hat{e}_1$ is the principal's conjecture about the choice of effort in the first period, given the incentives the agent was provided in that period.

Given that the agent cannot commit to participate in period 2, his certainty equivalent for that period must be no smaller than his reservation equivalent, which we normalize to be zero. Thus we must have $E(l_2|x_1) - C(e_2) - (1/2)r\beta_2^2 v_2 \geq 0$. It follows that the second-period fixed wage component α_2 must satisfy $\alpha_2 \geq A - \beta_2 \gamma x_1$, where A is a number that is independent of the first-period signal x_1. Given that α_2 is restricted to be a linear function of x_1, we must then have $\alpha_2 = (A + a) - \beta_2 \gamma x_1$, where $a \geq 0$ is also independent of x_1. The agent´s second-period certainty equivalent is then equal to a. The principal may want to set $a > 0$ in order to secure that the agent plans ex ante to participate in both periods.

The fact that the second period compensation depends (via α_2) on the first period signal x_1 distorts the agent's first period choice of effort. To see this consider the following experiment. Assume the agent reduces his effort relative to the principal's conjecture by de_1 in the first period. From the second period compensation rule it follows that such a reduction increases the expected second period payment by $\gamma\beta_2\, de_1$. This is what drives the ratchet effect in the model. The effective first period incentives, the incentives the agent considers when he chooses effort in period 1, is therefore not β_1, but $\beta = \beta_1 - \gamma\beta_2$. (This holds provided the agent plans to participate also in period 2.) The agent chooses the level of effort in the first period that yields $C'(e_1) = \beta$. Since the cost function is quadratic, we can write $e_1 = \beta$.

The sum of the agent's and the principal's intertemporal certainty equivalents is given by $TCE = B(\beta) - C(\beta) + B(\beta_2) - C(\beta_2) - (1/2)r\,\mathrm{var}(l_1 + l_2)$. The variance of the intertemporal wage may be written as $\mathrm{var}(l_1 + l_2) = \mathrm{var}\,E(l_1 + l_2|x_1) + E\,\mathrm{var}(l_1 + l_2|x_1) =$ $\mathrm{var}(l_1 + E(l_2|x_1)) + E\,\mathrm{var}(l_2|x_1)$, which is equal to $\beta_1^2\nu + \beta_2^2\nu_2$. Using $\beta_1 = \beta + \gamma\beta_2$ and the definition of the single period value function given by (1), we may then write,

$$TCE = B(\beta) - C(\beta) - \frac{1}{2}r\nu(\beta + \gamma\beta_2)^2 + w(\nu_2).$$

The principal chooses β (or equivalently β_1) to maximize this TCE. The maximal value is given by,

$$W(\nu) = \max_{\beta}\left\{B(\beta) - C(\beta) - \frac{1}{2}r\nu(\beta + \gamma\beta_2)^2 + w(\nu_2)\right\}. \tag{2}$$

We know from the discussion of the static case that the second-period incentive wage is a function only of ν_2; $\beta_2 = \beta_2(\nu_2)$, and furthermore that $\partial\beta_2/\partial\nu_2 < 0$.

Finally, the principal sets the first-period fixed wage component α_1 such that the agent´s intertemporal certainty equivalent equals its reservation value, which we take to be zero. By adjusting α_1 and α_2 such that the agent´s second-period certainty equivalent (denoted

a above) is sufficiently large, the principal can be assured that the agent plans to participate in both periods.

Two tasks and two agents.

The value in (2) is obtained if one agent is given a single task. For two symmetric agents and two tasks, which are symmetric except for a potential difference in the measurement variances (ν and ν', respectively), the intertemporal value if tasks are not shared is $W(\nu)+W(\nu')$. (It is assumed that the error terms are independent across tasks). If on the other hand the tasks are shared, the intertemporal value becomes $2W(\nu+\nu')$. The latter value is obviously larger than the former if the single-task value function $W(\nu)$ given by (2) is increasing in the variance ν.

From (2) it is clear that the second period variance of the information signal has an influence on first period profits. Differentiation of the maximum value function with respect to the variance of the measurement error term gives us the exact effect. The indirect effects of a change in the variance, the effects that go via the incentives, disappear because incentives are optimally chosen initially. We can therefore write,

(3) $$\frac{\partial W}{\partial \nu} = -\frac{r}{2}(\beta+\gamma\beta_2)^2 - r\nu(\beta+\gamma\beta_2)\gamma\frac{\partial \beta_2}{\partial \nu_2} - \frac{1}{2}r\beta_2^2(1-\gamma^2)\nu.$$

The first and the last terms are negative, the second is positive since $\partial\beta_2/\partial\nu_2 < 0$

Recall that the question we are interested in is whether the principal should let workers be jointly responsible for tasks or if it is better to separate tasks. In the static case it is best to separate tasks (Proposition 1) since separation reduces the agent's income variance for a given effort choice, and in the complete contract framework the value of the principal-agent relationship is decreasing in this variance. Equation (3) tells us that such an unconditional statement about job design cannot be made in an intertemporal principal-agent relationship. The increase in the variance of the workers' income which follows from sharing tasks between them, has a positive dynamic effect. It reduces the ratchet effect. Holding other factors constant we can see from (3) that the beneficial dynamic effect is more important the more risk averse agents are, the higher the variance of the measurement error is, and the more correlated they are over time.

To state more potent conclusions about the relative importance of the dynamic incentive effect, we need a more specific model. In Appendix A we parametrize the benefit function B() and show that there is a range of parameter values for which the dynamic benefits from offering jobs with mixed tasks and joint responsibility dominate the static losses imposed by such assignments. Technically this means that there are parameters such that the optimal value of the intertemporal agency relationship is increasing in the variance of the measurement of the agents' performance, that is, where $\partial W/\partial \nu > 0$. We can therefore make the following statement.

Proposition 2. For the model given above, there are parameter values such that it is beneficial for the principal to offer jobs where workers are jointly responsible for tasks.

What practical implications do our observations have? When Holmstrom and Milgrom [1991] discuss the static multitask problem and the principle of task separation (stated as Proposition 1 here), they acknowledge that they leave out many important elements that will have implications for optimal task assignment and job design. The virtue of their model, they say, is that "it is structured so that incentive considerations alone determine the optimal [job design] solution" . In their model static incentive considerations give an unconditional answer; to separate tasks. We also operate within the incentive paradigm, and we find that the results on optimal task assignment and job design are not robust. If it is costly to separate tasks, say if some of the other factors left in the dark in the incentive model draw in the direction of joint responsibility, one may find that, based on a complete contract framework (the Holmstrom Milgrom model) one would recommend the principal to alter the organisation structure and separate jobs, while the conclusion is the opposite in our model where intertemporal commitment cannot be made. Proposition 2 implies that occasionally it will be optimal for principals who do not have to think about existing job arrangements, e.g. a principal who creates a new organization, to offer jobs that give workers joint responsibility for a task.

Team production and incentives.

The foregoing analysis has some interesting implications for incentive issues in team production. The nature of some tasks or manufacturing systems may require that production is organized in work teams, in which only the aggregate output and not each individual worker´s contribution is observable. A negative effect of this organizational form is the spur that agents have to free-ride on the contributions made by others, because there are no - or only weak - ties between individual performance and individual compensation (Alchian and Demsetz (1972), Holmstrom (1982)). It appears that a partial remedy for this problem could be obtained by introducing monitoring systems that provided information about individual performance. This is indeed true in a static (or full commitment) setting; the principal would then generally gain if she had access to individual performance measures. Due to the adverse dynamic effects generated by ratcheting, it is not necessarily true, however, in a context with limited intertemporal commitment.

To illustrate this point, consider the following simple example. There are two identical agents (*i* and *j*) who contribute outputs $x_h = e_h + u_h$, where h=i,j, to a team. Effort costs are quadratic as before. Suppose that initially only the team´s aggregate output $x = x_i + x_j$ is observable. The two stochastic terms, u_i and u_j, are independent with variances ν and ν', respectively. The principal values the output according to its expectation $E(x) = e_i + e_j$. Given linear incentives it is straightforward to see that the optimal static value (the maximal *TCE*) for the team can be written as $2w(\nu + \nu')$, where w is the single-agent static value; $w(\nu) = \max_\beta \{\beta - C(\beta) - (r/2)\beta^2 \nu\}$.

Suppose it becomes possible to measure individual performance (although still with errors), so that the individual contributions x_i and x_j can be observed (and contracted upon). The optimal static value is then $w(\nu)+w(\nu')$. Since $w()$ is decreasing, the latter value exceeds the value $2w(\nu+\nu')$ obtained when only the team's aggregate output can be observed. This confirms that in the static case it is beneficial to get access to individual performance measures. This argument is exactly parallel to the argument given earlier for why task separation is better than task sharing in a static context. There it was also shown that task separation was not necessarily best if the principal could not commit herself to future wage contracts. It is clear that exactly the same argument can now be applied to show that access to individual performance measures is not necessarily an advantage when the principal cannot commit. This illustrates again that the conventional wisdom developed in a static setting does not necessarily remain valid in a dynamic setting.

Our argument in favour of shared responsibility for tasks is incentive based.[7] We have already indicated that there may be other reasons why this organization structure will perform better than a hierarchical structure with extencive degree of task division and specialisation. One such argument is that work teams are more flexible to do adjustments if this becomes necessary, say if there are changes in demand or in technology. Aoki [1988] argues that this is one of the reasons why the Japanese industry, which uses team production extensively, has been so successful compared to its western competitors, which traditionally have been organized as hierarchical structures with emphasis on work specialization.

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[7] Itoh [1991, 1992] argues in favour of joint responsibility in a static model. He shows that it can be beneficial to have access only to an aggregate measure of team production if workers can observe each others performance and can make side-contracts contingent on individual effort. The principal will then organize production in work teams and let individual compensation be dependent on what the team achieves. The fact that workers can observe each others efforts solves the free-raider problem, and when this problem is eliminated the income risk is reduced if several workers share the responsibility for one task.

Optimal grouping of tasks.

We left the problem of optimal grouping of tasks when we started the formal analysis. But it is clear that the lack of intertemporal commitment has implications for this question as well.[8] Static incentive considerations tell principals to group together tasks that have (approximately) the same degree of difficulty in performance measurement. For example, suppose there are four tasks (*a,b,c,d*) and two workers (*i,j*). Suppose the workers are identical, and the tasks symmetric in all repects except that it is easy to measure performance for two of them (*a,b*) but difficult for the other two. The principal should then group tasks *a* and *b* together and let worker *i* have the responsibility for these, while *j* should be given responsibility for *c* and *d*. This advice follows from the principle of equal pay; workers must be given the same compensation across tasks in order to pay adequate attention to all of them. The principal must therefore give the same incentives to all tasks she has grouped together if she wants something to be done on all of them. If the principal groups together tasks with different measurability she ties her hands; she cannot then give incentives to tasks which are easy to measure without at the same time expose the worker to a lot of income variance (because the same incentives must be given to the hard-to-measure tasks).

We do not have to spell out the whole model to see a how a lack of intertemporal commitment adds complexity to the question of optimal grouping of tasks. The way tasks are grouped together influences the intertemporal information revelation problem. One way to reduce the ratchet problem is to group together tasks of different performance observability. In an intertemporal setting it might therefore be optimal to group together tasks *a* and *d*. If the same worker is given the responsibility for these two tasks, he is offered low powered incentives, and this alleviates the ratchet problem.

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[8] We are grateful to Meg Meyer for pointing this out to us.

3. Limited commitment and the regulation of outside activities.

We will now turn to optimal regulation of outside activities. Principals can often use bureaucratic rules to regulate the agents' possibilities to pursue private projects while they are at work. We follow Holmstrom and Milgrom (1991) and assume that the private projects or outside activities do not benefit the principal directly; they contribute to her payoff only indirectly by making it more enjoyable for the worker to go to work. The principal can therefore reduce her compensation to the agent if she allows work on outside activities. The cost associated with giving too much discretion is that the agent will ignore the workplace task which he is hired to do. These observations lead to the following design question: Given the costs and the benefits of allowing workers to pursue outside activities, how much discretion should they be given?

Based on their static model, Holmstrom and Milgrom (1991) derive the following principle: If it is easy to measure how a worker performs on his workplace task, he should be given relatively large degrees of freedom to pursue personal business activities. This principle emerges because a worker will be given high powered incentives if it is easy to measure performance, and this reduces the hazard that he will ignore the main task even if he is given a lot of discretion to do outside activities. To see why, consider a case where effort can be perfectly monitored. The principal will then pay the agent the true marginal value of his effort and the agent will - without any associated risk costs - internalise the true value of spending time and effort on outside activities. That is, he will engage himself in such activities only if they are desirable also from the principal's point of view. In this case the agent should be given full discretion to pursue outside activities. For other tasks it may be harder to monitor how much effort the agent puts into his main job. Incentives must then be made low powered in order to reduce the agent's exposure to risk. The possibility to pursue outside activities should then be more rigidly regulated, since low powered incentives makes it more attractive for the agent to direct his attention to these activities.

Also the question of optimal regulation of outside activities gets more delicate as the assumption of complete intertemporal commitment is relaxed. In a two period framework it is clear from our static analysis above that a higher measurement variance leads to less powerful incentives in the second period. The effect that a higher measurement variance has on first period incentives is, however, more complex. A higher measurement variance makes it costly to use performance pay to compensate the agent, and this draws in the direction of less powerful incentives. This is the only effect which is present in the static model, but now, in a two period framework, there is another effect which influences first period incentives: The reduction in second period incentives mitigates the ratchet problem, and this draws in the direction of more high powered effective incentives in the first period. In a formal set-up we can show that the second of these effects may dominate, so the first-period effective incentives increase as the measurement variance increases. This is interesting because it tells us that high powered incentives and the discretion for the agent to pursue private projects go together. The principal will therefore gain if she, in response to an increase in the measurement variance, allows the agent more freedom to pursue other activities. This is the exactly the opposite of what it is optimal to do in a static setting.

The basic structure of the model is the same as the two period model we used to study the task separation problem. The difference is that the agent now, in addition to one workplace activity, can work on different outside activities: The agent can pursue private business while he is at work. Suppose there is a continuum of such activities indexed by $k \in I = [1, L]$[9]. The private value (per period) for an agent who supplies effort e_k into activity k is given by $v(e_k, k)$. This value is positive for all $e_k > 0$, furthermore it is assumed to be concave in e_k and decreasing in k. The principal can control the agent´s work on outside activities only by exclusion, that is by limiting the agent's discretion

[9]Apart from the continuity assumption, which we invoke to simplify the "comparative dynamics" analysis, the static version of the model is entirely similar to the set-up in Holmstrom and Milgrom [1991].

(what we called bureaucratic rules above). Technically the principal regulates outside activities by setting a limit $K < L$ on activities the agent is allowed to engage in while he is at work. We assume that the agent is hired to do only one task and that the outside activities do not directly benefit the principal[10].

Consider now the static case. If the agent chooses effort e on his workplace activity and effort e_k on the k'th outside activity, and he is compensated with a linear compensation scheme at work, the certainty equivalent of his income is

$$CE = \beta e + \alpha + \int_{k=1}^{K} v(e_k, k)dk - C(e + \int_{k=1}^{K} e_k dk) - \frac{1}{2}(r\beta^2 v),$$

where v is the variance associated with the measurement of his workplace activity. The cost function is quadratic as before and all activities, the workplace activity and the outside activities, are perfect substitutes, so $C(e + \int_{k=1}^{K} e_k dk) = (1/2)\left[e + \int_{k=1}^{K} e_k dk\right]^2$.

The first order conditions for an interior solution to the agent's optimization problem are,

$$\beta = C'(e + \int_{k=1}^{K} e_k dk) = e + \int_{k=1}^{K} e_k dk$$
$$\beta = v'(e_k, k).$$

The principal values the agent´s output according to its expected value (e). We can then write the sum of the agent's and the principal's certainty equivalents as

$$TCE = e + \int_{k=1}^{K} v(e_k, k)dk - C(e + \int_{k=1}^{K} e_k dk) - \frac{1}{2}(r\beta^2 v)$$
$$= \beta - \frac{1}{2}\beta^2 + \int_{k=1}^{K}\left[v(e_k, k) - e_k\right]dk - \frac{1}{2}(r\beta^2 v).$$

The principal chooses the power of the incentives (β), and the limit on outside activities (K) which solve the following two first order conditions:

---

[10] Of course the outside activities benefits the principal indirectly since the agent finds it more enjoyable to go to work if he is allowed to pursue private business while he is there. The principal can therefore reduce her compensation to the agent if she allows him to work on outside activities.

$$0=\frac{\partial TCE}{\partial\beta}=1-\beta\left[1+r\nu^2\right]+(\beta-1)\int_{k=1}^{K}\frac{\partial e_k}{\partial\beta}dk \quad \text{(since } v'=\beta\text{)}$$

$$0=\frac{\partial TCE}{\partial K}=\left[v(e_K,K)-e_K\right].$$

(The second equation tells the principal that she should allow outside activities up to the level where the net contribution of the last one is zero.)

Let $w(\nu)$ be the maximal value of the TCE , i.e., the value when the optimal incentive wage $\beta=\beta(\nu)$ and the optimal limit on outside activities $K=K(\nu)$ are chosen. If the variance in the measurement (ν) decreases, incentives become more powerful and the agent's possibility to work on outside activities less rigidly regulated: High powered incentives and freedom for the agent to undertake outside activities go together. The following parametric example illustrates these effects.

Example: Let $v(e_k,k)=(1/k)\left[1-(1-e_k)^2\right]$, $k\in[1,2]$. Then $\beta=v'(e_k,k)=(2/k)(1-e_k)$, so $\int_{k=1}^{K}(\partial e_k/\partial\beta)\,dk=-\int_{k=1}^{K}(k/2)dk=-(1/4)(K^2-1)$. The optimal incentive wage solves $0=1-\beta[1+r\nu^2]+(1-\beta)(1/4)(K^2-1)$, which gives

$$\beta=\frac{c}{c+r\nu^2}, \text{ where } c\equiv 1+\frac{1}{4}(K^2-1).$$

The optimal limit (K) on outside activities is determined by $v(e_K,K)-e_K=0$. Substituting for $e_K=1-K\beta/2$, this condition takes the form $[1-(K\beta/2)^2]/K-[1-K\beta/2]=0$, which yields $\beta=2(1-1/K)$. It is straightforward to see that both $\beta(\nu)$ and $K(\nu)$ are decreasing in the variance ν.

We will now turn to the two period model to examine whether it still holds that the agent should be given less discretion to pursue outside activities when the variance in the measurement of the performance on the main activity increases. To analyse this issue we will draw a distinction between the measurement variance of the performance signal on the one side, and variance in performance due to uncertain intrinsic ability, on the other. We consider therefore the following specification of the performance signal;

$$x_t = e_t + a + u_t,\ t = 1,2,$$

where a represents the agent's time-invariant intrinsic ability, and u_t represents the measurement error in period *t*. The variables a, u_1 and u_2 are independent and normally distributed with zero means and variances

$$\operatorname{var} a = s, \quad \operatorname{var} u_t = \tau,$$

respectively. This yields $\operatorname{var} x_t = s + \tau \equiv \nu$, and the intertemporal correlation coefficient is then given by:

$$\gamma \equiv \operatorname{corr}(x_1, x_2) = \frac{s}{\tau + s} = \frac{s}{\nu}.$$

The question we will analyse is if an increase in the measurement variance (τ) can lead to more discretion for the agent, i.e., if the optimal limit K increases as τ increases.

We assume that *the principal can neither commit to future incentive schemes nor to limits on outside activities*. She will therefore choose these optimally in period 2, based on what she has observed in period 1. This yields for period 2 a bonus ($\beta_2(\nu_2)$) and a limit on outside activities ($K_2(\nu_2)$), both determined as functions of the conditional variance $\nu_2 = \nu(1-\gamma^2)$ by the first order conditions as they are given above for the static case. The second period value is similarly $w(\nu_2)$. Since ν_2 is increasing in τ - indeed, $\partial \nu_2 / \partial \tau = 1 + \gamma^2$ - it follows that $\beta_2(\nu_2)$ and $K_2(\nu_2)$ both decrease as τ increases.

Let β be the effective incentive wage in the first period. The principal will choose β and the first period limit $K = K_1$ to maximize the intertemporal TCE, given by;

$$\beta - \frac{\beta^2}{2} + \int_{k=1}^{K} [v(e_k, k) - e_k] dk - \frac{r}{2}(\beta + \gamma\beta_2)^2 \nu + w(\nu_2),$$

where e_k satisfies $v'(e_k, k) = \beta$. Given interior solutions, the first order conditions for β and K are

$$0 = 1 - \beta + (\beta - 1) \int_{k=1}^{K} [\frac{\partial e_k}{\partial \beta}] dk - r\nu(\beta + \gamma\beta_2)$$

$$0 = v(e_K, K) - e_K.$$

If the second period incentive wage β_2 were kept fixed, an increase in the measurement variance τ would lead to a reduction in the first period effective incentive wage β, and therefore also to a more strict regulation of outside activities (reduction in K) in the first period. But the crux of our argument is precisely that the second period bonus will not stay fixed as the variance τ increases. A higher variance reduces the second period incentive wage ($\beta_2(\nu_2)$) and this leads ceteris paribus to higher effective incentives (β) in the first period.

If the latter of these effects dominates, it means that effective incentives in the first period may increase as it gets harder to measure performance . And then, since we know that the limit K moves in the same direction as β, we could conclude that the agent is given more discretion to pursue outside activities in the first period if the measurement variance increases. The following proposition, which is proved in Appendix B, states that such comparative static results are indeed feasible.

Proposition 3. There are cases where the following holds: As the measurement variance (τ) increases, the principal gives the agent more discretion in the first period to pursue private business activities.

4 Discussion and final remarks.

The design of jobs becomes an interesting problem in more complex - and realistic - organisational structures than the one portrayed in the standard economic model of a principal-agent relationship . We have studied design issues which arise when a principal hires agents to do many different tasks (or multidimensional tasks, see footnote 1). Holmstrom and Milgrom argue convincingly that multitask problems are abundant in economic organisations, and that in these relationships "job design is an important instrument for the control of incentives" (Holmstrom and Milgrom [1991, p. 25]).

We have shown in the main text that the principles for job design that emerge from a static analysis of the multitask agency problem, can be turned totally around if we drop the assumption of complete intertemporal commitment. In a repeated agency without intertemporal commitment it can be optimal to offer jobs in which workers share the responsibility for a task, it can be optimal to group together tasks with different measurability of performance, and finally we have shown that the principal may give her workers more freedom to pursue outside activities the harder it is to measure performance on the main task. In such cases the principal is adviced to organize jobs in exactly the opposite way of what she should do in the one shot case.

The ratchet effect is the reason why the rules for good job design can change so fundamentally as we go from the one-shot to the repeated agency problem. We know that in the standard principal-agent relationship the benefits of using incentives to get more efficient motivation of workers must be compared with the costs imposed as workers get more exposed to income uncertainty. An additional cost dimension arises if agents are hired to do multitask jobs. The use of an incentive wage can then distort the agents' allocation of time and effort between different tasks. The rules for job design advocated in the static relationship work well since they minimize the costs of using incentive wages to compensate workers. That is, the design allows the principal to use high powered incentives. But high powered incentives add fuel to the ratchet effect. If the negative consequences of this problem are important, it can be better for the principal to choose a job design which increases the static costs of using incentive wages, and therefore leads to more low powered incentives.

Appendix A: Proof of Proposition 2.

Let $B(e)=(1/\varepsilon)e^{\varepsilon}, 0<\varepsilon\leq 1,$ and recall that we have assumed a quadratic specification of the effort cost function, $C(e)=(1/2)e^2$. In period 2 the agent chooses effort $e_2=\beta_2$ and the principal's value in that period is therefore,

$$w(\nu_2)=\max_{\beta_2}\left[\frac{1}{\varepsilon}\beta_2^{\varepsilon}-\frac{1}{2}\beta_2^2-\frac{1}{2}\beta_2^2 r\nu_2\right].$$

The optimal second period incentive wage is then

$$\text{(A1)} \qquad \beta_2=\left[1+r\nu_2\right]^{-\eta},$$

where $\eta\equiv\dfrac{1}{2-\varepsilon}$ and $\nu_2=(1-\gamma^2)\nu$.

Solving for the optimal first period effective wage (β) - see (2) in the text - we find that this wage must satisfy

$$\text{(A2)} \qquad 1=(1+r\nu)\beta^{2-\varepsilon}+r\nu\gamma\beta_2\beta^{1-\varepsilon}.$$

We will show that the intertemporal value $W(\nu)$ is increasing in ν if r is sufficiently large and γ is sufficiently close to unity. From (A1) it follows that $\beta_2(r\nu)^{\eta}\to(1-\gamma^2)^{-\eta}\equiv b_2$ as $r\to\infty$. From (A1) we also find $(r\nu)^{\eta}\nu(\partial\beta_2/\partial\nu)=-\eta(1-\gamma^2)\left[r\nu/(1+r\nu_2)\right]^{\frac{3-\varepsilon}{2-\varepsilon}}\to-\eta(1-\gamma^2)^{-\eta}$ as $r\to\infty$.

Next we find from (A2) that $\lim_{r\to\infty}\beta(r\nu)^{\eta}=b$, where b is a solution to

$$\text{(A3)} \qquad 1=b^{2-\varepsilon}+\gamma b_2 b^{1-\varepsilon}$$

From the expression (3) for $(\partial W/\partial\nu)$ we then obtain:

$$\lim_{r\to\infty}(r\nu)^{2\eta}\left(\frac{2}{r}\frac{\partial W}{\partial\nu}\right)=-(b+\gamma b_2)^2+2\gamma(b+\gamma b_2)\eta(1-\gamma^2)^{-\eta}-b_2^2(1-\gamma^2)\equiv\Omega(\gamma).$$

We finally show that $\Omega(\gamma)>0$ for γ close to 1. To see this note that $b_2(1-\gamma^2)^{\eta}=1$, and hence (A3) yields $\lim_{\gamma\to 1}(1-\gamma^2)^{\eta}b=0$. From this it follows that

$$\lim_{\gamma\to 1}(1-\gamma^2)^{2\eta}\Omega(\gamma) = -1+2\eta-0 = \frac{\varepsilon}{2-\varepsilon} > 0.$$

This proves that $\Omega(\gamma)>0$ for γ close to 1, and hence that $(\partial W/\partial \nu)>0$ if, in addition, r is sufficiently large.□

Appendix B: Proof of Proposition 3.

Let the value of an outside activity be given by the quadratic function $v(e_k,k) = (1/k)\left[1-(1-e_k)^2\right]$, where $k \in [1,2]$. The optimal second period bonus β_2 and the optimal limit K_2 on outside activities in the second period are then given by (see the example in the text)

(B.1) $$\beta_2 = \frac{c_2}{[c_2 + r(1-\gamma^2)v]},\quad c_2 \equiv 1 + \frac{(K_2)^2-1}{4}, \text{ and}$$

(B.2) $$K_2 = 2/(2-\beta_2),$$

This holds provided that there is an interior solution (where the agent exerts a positive effort for the principal, and where $1 < K_2 < 2$).

One can check that the effort exerted for the principal will be positive if $\beta_2 > (K_2-1)/c_2$. (Since effort costs are quadratic, the agent's total effort equals β_2. The effort on the main task is therefore positive if $\int_{k_2=1}^{K_2} e_k dk < \beta_2$. Since e_{K_2} is given by $\beta_2 = v'(e_{K_2}, K_2) = 2(1-e_{K_2})/K_2$, we can write that condition as $\beta_2 > (K_2-1)/c_2$.)

We are looking for parameter values that will yield $\partial\beta/\partial\tau > 0$, where β is the optimal effective incentive wage in the first period. Since this wage depends on β_2 we need an expression for $\partial\beta_2/\partial\tau$. From (B.2) we get $(\partial K_2/\partial\tau) = \left((K_2)^2/2\right)(\partial\beta_2/\partial\tau)$, which clearly confirms that K_2 and β_2 either both increase or both decrease as the variance increases.

From (B.1) we then obtain

$$\frac{\partial\beta_2}{\partial\tau} = \frac{-r(\beta_2)^2(1+\gamma^2)}{c_2} + rv_2\left(\frac{\beta_2}{c_2}\right)^2\left(\frac{K_2}{2}\right)\left(\frac{\partial K_2}{\partial\tau}\right).$$

Substituting for $\partial K_2/\partial\tau$ finally yields

$$\frac{\partial\beta_2}{\partial\tau} = \frac{-r(\beta_2)^2(1+\gamma^2)/c_2}{1 - rv_2(\beta_2/c_2)^2(K_2/2)^2 K_2}.$$

The optimality condition for the first-period incentive wage takes the form

$$\beta = \frac{c_1 - rv\gamma\beta_2}{c_1 + rv},$$

where $c_1 = 1 + (K^2 - 1)/4$, and K is the limit on outside activities in the first period.

This yields

$$\frac{\partial\beta}{\partial\tau} = \left.\frac{\partial\beta}{\partial\tau}\right|_{K\text{ Fixed}} + \frac{1-\beta}{c_1 + rv}\frac{K}{2}\frac{\partial K}{\partial\tau}, \quad \text{where}$$

$$\left.\frac{\partial\beta}{\partial\tau}\right|_{K\text{ Fixed}} = \frac{r}{(c_1 + rv)^2}\left\{-s\left(\frac{\partial\beta_2}{\partial\tau}\right)(c_1 + rv) - (c_1 - r\gamma v\beta_2)\right\}.$$

From the optimality condition for K we obtain $\beta = 2(1 - 1/K)$ and hence $\partial K/\partial\tau = (K^2/2)(\partial\beta/\partial\tau)$. Then we have

$$\frac{\partial\beta}{\partial\tau} = \left.\frac{\partial\beta}{\partial\tau}\right|_{K\text{ Fixed}} + \frac{2-K}{c_1 + rv}\left(\frac{K}{2}\right)^2\frac{\partial\beta}{\partial\tau}.$$

Since $1 \le K \le 2$ and $c_1 \ge 1$ it follows that $(\partial\beta/\partial\tau)$ has the same sign as $(\partial\beta/\partial\tau)|_{K\text{ Fixed}}$.

We shall prove that there are parameter values such that this derivative is positive. Let

$$A \equiv -s\frac{\partial\beta_2}{\partial\tau} = \frac{rs\beta_2^2(1+\gamma^2)}{c_2 - rv_2\beta_2^2(K_2/2)^2 K_2/c_2}.$$

Consider the following parameter values,

$rs = 4$

$r\tau = \frac{[3c_2 + (9c_2^2 + 64)^{1/2}]}{2} - 4, \quad \text{where } c_2 = 1 + \frac{[(8/7)^2 - 1]}{4}.$

Since $r\nu_2 = r\nu(1-\gamma^2) = (rs + r\tau)[1 - (rs/(rs + r\tau))^2]$, we see that $c_2/(c_2 + r\nu_2) = 1/4$. It follows that $\beta_2 = 1/4$ and $K_2 = 8/7$ are optimal in period 2. It is then straightforward to check that

$1/4 < A < 1.$

(The enumerator in the expression for A is evidently larger than $(1+\gamma^2)/4$ and smaller than 1/2. One can check that $1<r\tau<2$ and hence that $\gamma^2 > 4/9$, implying that $(1+\gamma^2) > 1+4/9 > c_2$. This yields $A > 1/4$. On the other hand , since $c_2 > 1$ and $r\nu_2 < r\nu < 6$, the denominator in the expression for A exceeds $1\text{-}6(1/4)^2(8/14)^2(8/7)>1/2$, hence $A < 1$.)

The derivative $(\partial\beta/\partial\tau)|_{K\ \text{Fixed}}$ has the same sign as $A(c_1 + r\nu) - (c_1 - r\gamma\nu\beta_2) =$ $(A-1)c_1 + Ar\nu + 1$, where the equality follows from $r\gamma\nu = rs = 4$ and $\beta_2 = 1/4$. Since $A < 1$ and $c_1 \le 1 + (2^2 - 1)/4$, the last expression involving A exceeds $(A-1)(1+3/7) + 1 + Ar\nu$. Since $A > 1/4$ and $r\nu = rs + r\tau > 5$, this again exceeds $1 - 3/28 - 3/7 > 0$. Hence we have shown that there are parameter values such that $(\partial\beta/\partial\tau)|_{K\ \text{Fixed}} >0$. This inequality implies $\partial\beta/\partial\tau>0$ and $\partial K/\partial\tau>0$. Note also that, since the last two inequalities are strict, the statement in Proposition 3 holds for a set of parameter values that has positive measure.□

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