Job design with conflicting tasks reconsidered

Schmitz, Patrick W.

October 2012

Job Design with Conflicting Tasks Reconsidered

Patrick W. Schmitz*

University of Cologne, Staatswissenschaftliches Seminar,
Albertus-Magnus-Platz, 50923 Köln, Germany
and CEPR, London, UK

Abstract. A principal wants two sequential tasks to be performed by wealth-constrained agents. Suppose that there is an outcome externality; i.e., a first-stage success can make second-stage effort more or less effective. If the tasks are conflicting, the principal's profit-maximizing way to induce high efforts is to hire one agent to perform both tasks (so that the prospect to get a larger second-stage rent after a first-stage success motivates the agent to work hard in the first stage). In contrast, when there is an effort externality (i.e., first-stage effort reduces or increases the probability of a second-stage success), then the principal prefers to hire two agents whenever the tasks are conflicting.

Keywords: moral hazard; limited liability; conflicting tasks; synergies

JEL Classification: D86; L23; J33; M54

* *Address for correspondence:* University of Cologne, Department of Economics, Albertus-Magnus-Platz, 50923 Köln, Germany. Tel.: +49 221 470 5609; fax: +49 221 470 5077. *E-mail address:* patrick.schmitz@uni-koeln.de. I would like to thank three anonymous referees and an associate editor for making very valuable comments and suggestions. Moreover, I have benefitted from helpful discussion with Eva Hoppe.

1 Introduction

Decision-makers often have to choose between letting one agent be responsible for two tasks, or letting two different agents be responsible for one task each. For example, when an infrastructure facility is built (first task) and subsequently operated (second task), it has to be decided whether the same contractor or two different contractors should be in charge of the two tasks.[1] When a new government is formed, there can be a single department responsible for different fields, or there can be separate departments in charge of the different fields.[2]

In an important contribution, Dewatripont and Tirole (1999) have pointed out that the different tasks which a principal delegates to an agent can often be conflicting; i.e., one task (e.g., promoting growth or creating jobs) can be directly detrimental to another task (e.g., protecting the environment or enhancing social security). This may lead the principal to delegate these tasks to different agents, since it appears to be difficult to motivate one agent to work on two conflicting tasks. While Dewatripont and Tirole (1999) considered an incomplete contracting model, Bolton and Dewatripont (2005, Section 6.2.2) show that similar issues can also be fruitfully studied in a complete contracting framework.

[1] For instance, in the recent case of two new Ohio River spans, the only method allowed under current Kentucky law is the traditional approach, which means that there are different contractors. Yet, the alternative option of having one contractor in charge of both tasks is also currently discussed, which would require action by the Kentucky General Assembly (*The Courier-Journal*, October 6, 2011). In the case of the Port of Miami Tunnel, a major construction project in Florida with an estimated cost of 1 billion U.S. dollars, it was decided to let the private contractor MAT Concessionaire LLC be in charge of both tasks (*Miami Herald*, April 17, 2010).

[2] For instance, in the current Government of New South Wales led by Premier Barry O'Farrell, there now is a so-called "super-ministry" led by Andrew Stoner, who is both Minister for Trade and Investment and Minister for Regional Infrastructure and Services (*The Sydney Morning Herald*, April 3, 2011).

Specifically, Bolton and Dewatripont (2005) assume that the tasks are performed *simultaneously* and that there is an *effort externality* between the tasks, such that effort in one task may reduce the success probability of another task.[3] Their main finding is that if the conflict between the tasks is sufficiently strong, then the principal prefers to hire two different agents to work on the two tasks. In contrast, when the tasks are not conflicting, only one agent should be in charge of both tasks, since it is cheaper for the principal to incentivize one agent (a bonus must only be paid when both tasks are successful).

In the present paper, we consider tasks that for technological reasons can only be performed *sequentially*. For instance, construction of a facility must take place before its operation. In the case of sequential tasks, it is plausible that there may be an *outcome externality* between the tasks. When the second task is performed, the outcome of the first task is already realized, and this outcome may affect the success probability of the second task. (If instead an effort externality were present, then the effort expended on the first task –not the outcome– would affect the success probability of the second task.)

For example, in an infrastructure project, effort may be exerted in an initial phase to come up with an innovative design that is particularly cheap to build. In the subsequent operation stage, the costs of infrastructure maintenance may (positively or negatively) depend on the outcome of the first stage (i.e., whether or not an innovative facility was built). Similarly, a principal may want an agent to sell a durable good (say, a tablet computer or a mobile phone) today, but she may also want an agent to sell the next generation of the device tomorrow. In this case, if a consumer has already bought the durable good today, then it can be more difficult to sell the next generation product to him tomorrow. Again, it is plausible that it is the first-stage outcome (i.e., whether or not the good was successfully sold) and not the first-stage effort

[3] As an illustration, consider a principal who wants two goods to be sold. When the goods are imperfect substitutes, then effort to sell one product may make it more difficult to sell the other product.

which makes the second-stage task more easy or more difficult.

The main finding of the present paper is that when there is an outcome externality, then the findings of Bolton and Dewatripont (2005) are overturned. If the tasks are in conflict, so that a success in the first task makes effort in the second task less effective, then the principal is better off when she hires only one agent in charge of both tasks. In contrast, if there are synergies between the tasks, then the principal prefers to hire two different agents for the two different tasks. The intuitive explanation is as follows. In the presence of limited liability, the principal cannot make the agent pay a fine when there is no success. Hence, the only possibility to motivate an agent to exert unobservable effort is to offer him a bonus when there is a success, so that the agent enjoys a rent.[4] In particular, when effort is not very effective in increasing the success probability, then the rent that the principal must promise the agent has to be large in order to give him an incentive to work hard.

Now consider a two-stage model. When exerting effort in the second stage becomes less effective, it becomes more difficult to motivate the agent in charge of the second stage to work, so that the principal has to increase the rent that she must leave to the agent when she wants to implement high effort. When the tasks are conflicting, an agent who is in charge in both stages now has an additional incentive to exert effort in the first stage, because by making second-stage effort less effective, he can increase the rent that he can enjoy in the second stage. In contrast, when there are synergies, it is better for the principal to hire two different agents, because a single agent would now be tempted to shirk in the first stage (and thus make second-stage effort less effective) in order to increase his second-stage rent.

It is important to note that this logic applies only if it is the outcome of the first stage that has an impact on the second stage. Specifically, we show that

[4] Laffont and Martimort (2002) use the term "limited liability rent" to distinguish the rent in moral hazard models with wealth constraints from the related concept of information rents that a principal has to leave to agents in adverse selection models.

when tasks have to be performed sequentially but there is an effort externality instead of an outcome externality, then the results are qualitatively similar to those obtained by Bolton and Dewatripont (2005).

By now, there is a large contract-theoretic literature on multi-task principal-agent problems in the presence of moral hazard.[5] Early contributions such as Holmström and Milgrom (1991) and Itoh (1994) were based on the trade-off between incentives and insurance when agents are risk-averse. As has been emphasized by Bolton and Dewatripont (2005, p. 234), traditional multi-task models were often focused on the effort-substitution problem (an agent who engages in different activities may have higher/lower effort costs when the tasks are substitutes/complements). In contrast, following Bolton and Dewatripont (2005), we consider a complete contracting framework with risk-neutral but wealth-constrained agents,[6] in which an agent's effort costs of performing a given task are independent of whether the agent is also in charge of another task. While many studies in the multi-task agency literature focus on simultaneous tasks, there are by now also some papers that explore settings in which tasks have to be performed sequentially; see in particular Hirao (1993), Schmitz (2005), Khalil et al. (2006), Berkovitch et al. (2010), Kräkel and Schöttner (2010, 2011), Müller (2011), and Ohlendorf and Schmitz (2012). Yet, these contributions do not consider conflicting tasks, which are the focus of the present paper.[7] Finally, so far there are only relatively few experimental

[5] For reviews, see Dewatripont et al. (2000), Laffont and Martimort (2002, ch. 5), and Bolton and Dewatripont (2005, ch. 6).

[6] Innes (1990), Pitchford (1998), and Tirole (2001) study related "efficiency wage" models in the contract-theoretic sense of Tirole (1999, p. 745) and Laffont and Martimort (2002, p. 174). See also Kragl and Schöttner (2011), who study whether a principal should hire one or two agents to perform simultaneous tasks in the presence of wage floors.

[7] Moreover, each paper also differs in other respects from the present model. For instance, in Hirao (1993) and Berkovitch et al. (2010), a project is selected in the first stage, while unobservable effort is exerted in the second stage only. In Schmitz (2005), no rent can be earned in the first stage and when high effort is always to be implemented, the principal

studies on multi-task moral hazard models. However, recently Hoppe and Kusterer (2011) have found evidence supporting Bolton and Dewatripont's (2005) findings in a large-scale laboratory experiment.[8]

The remainder of the paper is organized as follows. In section 2, a simple model with sequential tasks and outcome externalities is introduced. Section 3 characterizes the principal's optimal contract. The case of effort externalities is briefly discussed in section 4. Concluding remarks follow in section 5. All proofs have been relegated to the appendix.

2 The model

Consider a principal who wants two sequential tasks to be performed. The verifiable outcome of task $i \in \{1, 2\}$ is denoted by $q_i \in \{0, 1\}$. If task i is a success ($q_i = 1$), the principal obtains a revenue R, otherwise her revenue in stage i is zero. The principal can either employ a single agent to perform both tasks, or she can employ two different agents for the two different tasks. All parties are risk neutral. An agent has no wealth and his reservation utility is zero.[9] Effort on task $i \in \{1, 2\}$ is denoted by $e_i \in \{0, 1\}$. An agent who exerts

would never hire one agent in charge of both stages. In Ohlendorf and Schmitz (2012) and Müller (2011), the second-stage technology is independent of the first stage (see also Nieken and Schmitz, 2012, for a related laboratory experiment). Kräkel and Schöttner (2010) analyze an incomplete contracting model with short-term contracts, while in Kräkel and Schöttner (2011) there are always two agents hired in the first stage. Khalil et al. (2006) assume that there is an adverse selection problem in the second stage.

[8]In Hoppe and Kusterer's (2011) experiment, the agents were salespersons who could promote one or two products. When the products were substitutes, so that the tasks are conflicting in the sense of Bolton and Dewatripont (2005), high effort levels were observed significantly less often when there was one agent in charge of both tasks compared to the case of two agents. In the absence of conflict, the principal was better off when she hired just one agent, as predicted by Bolton and Dewatripont (2005).

[9]Notice that if the agents were not protected by limited liability, the principal could always attain the first-best solution by making an agent residual claimant; i.e. the principal

effort e_i incurs a disutility of effort ψe_i. The effort levels are not observable.

The probability that the first task is a success is given by $\Pr\{q_1 = 1\} = \alpha + \rho e_1$. The probability that the second task is a success is given by $\Pr\{q_2 = 1\} = \alpha + \gamma_{q_1} e_2$. Throughout, we assume that the parameters $\alpha, \rho, \gamma_0, \gamma_1$ are strictly positive and $\alpha < 1 - \max\{\rho, \gamma_0, \gamma_1\}$, so that the expressions that describe probabilities lie between zero and one. Observe that even if the agent shirks, there is a success with probability $\alpha > 0$.[10] Moreover, it may depend on the outcome of the first stage (q_1) how effective effort in the second stage is. Specifically, note that the two tasks are technologically *independent* if $\gamma_1 = \gamma_0$. We say that the two tasks are *conflicting* if $\gamma_1 < \gamma_0$. In this case, a success in the first stage makes effort in the second stage less effective (i.e., there is a negative outcome externality). In contrast, we say that the tasks are *synergistic* if $\gamma_1 > \gamma_0$. In this case, a success in the first stage makes effort in the second stage more effective (i.e., there is a positive outcome externality).

Note that since the two agents are identical, in a first-best world (i.e., if effort were contractible) it would make no difference whether the principal hires one or two agents. Following Bolton and Dewatripont (2005), we assume throughout that the principal's revenue R is sufficiently large so that she always wants to implement high effort. Hence, we can focus on the question whether the principal's expected costs are smaller when she hires one or two agents. To induce an agent to exert effort, the principal can offer him a wage scheme $w_{q_1 q_2} := w(q_1, q_2) \geq 0$ that is contingent on the outcomes of both tasks.

would simply leave her revenue to the agent in exchange for a suitable up-front payment, so that the expected payoff of the agent would be zero.

[10] Note that the first-best solution could always be attained if α were equal to zero, because then in case of a success the principal knew for sure that the agent has exerted high effort. The principal would then just reimburse the agent for his effort costs, so that the agent would make zero expected profit. In contrast, if α is strictly positive, there can also be a success when the agent shirks. Hence, the principal must leave a rent to the agent, because if the principal just offered to reimburse the agent's effort costs, the agent would get zero in expectation if he exerts effort, while he would get a positive rent if he shirks.

3 The main results

Suppose first that the principal has hired only one agent to perform both tasks. Since effort is unobservable, the principal must ensure that it is in the agent's self-interest to choose high effort. Hence, the agent's expected utility when he exerts high effort (incurring effort costs ψ) must be larger than his expected utility when he shirks. The incentive compatibility constraints ensuring that the agent exerts high effort in the second stage are

$$(\alpha+\gamma_1)w_{11}+(1-\alpha-\gamma_1)w_{10}-\psi \geq \alpha w_{11}+(1-\alpha)w_{10}$$

for the case that the first stage was a success ($q_1 = 1$) and

$$(\alpha+\gamma_0)w_{01}+(1-\alpha-\gamma_0)w_{00}-\psi \geq \alpha w_{01}+(1-\alpha)w_{00}$$

for the case that the first stage was a failure ($q_1 = 0$). The agent is willing to exert high effort in the first stage if the incentive compatibility constraint

$$\begin{aligned} & (\alpha+\rho)[(\alpha+\gamma_1)w_{11}+(1-\alpha-\gamma_1)w_{10}-\psi] \\ & +(1-\alpha-\rho)[(\alpha+\gamma_0)w_{01}+(1-\alpha-\gamma_0)w_{00}-\psi]-\psi \\ \geq\ & \alpha[(\alpha+\gamma_1)w_{11}+(1-\alpha-\gamma_1)w_{10}-\psi] \\ & +(1-\alpha)[(\alpha+\gamma_0)w_{01}+(1-\alpha-\gamma_0)w_{00}-\psi] \end{aligned}$$

is satisfied.

The principal's problem is to find a wage scheme $(w_{00,}w_{10}, w_{01}, w_{11})$ in order to minimize her expected costs

$$(\alpha+\rho)[(\alpha+\gamma_1)w_{11}+(1-\alpha-\gamma_1)w_{10}]+(1-\alpha-\rho)[(\alpha+\gamma_0)w_{01}+(1-\alpha-\gamma_0)w_{00}]$$

subject to the incentive compatibility constraints and the limited liability constraints $w_{q_1q_2} \geq 0$. Since the agent always has the possibility to choose low effort without incurring any costs, incentive compatibility and limited liability together imply that the agent's participation constraint is always satisfied.

Lemma 1 *Suppose the principal has delegated both tasks to one agent.*

(i) If $\gamma_0\gamma_1 + (\gamma_1 - \gamma_0)\alpha\rho \geq 0$*, it is optimal for the principal to offer the contract* $w_{00} = w_{10} = 0$*,* $w_{01} = \psi/\gamma_0$*, and*

$$w_{11} = \psi \frac{\gamma_0 + \rho(\alpha + \gamma_0)}{\rho\gamma_0(\alpha + \gamma_1)}.$$

Then her expected costs are

$$\left[\frac{\alpha + \rho}{\rho} + \frac{\alpha + \gamma_0}{\gamma_0}\right]\psi.$$

(ii) If $\gamma_0\gamma_1 + (\gamma_1 - \gamma_0)\alpha\rho < 0$*, the principal will offer the contract* $w_{00} = w_{10} = 0$*,* $w_{01} = \psi/\gamma_0$*, and* $w_{11} = \psi/\gamma_1$*. Then her expected costs are*

$$\left[(\alpha + \rho)\frac{\alpha + \gamma_1}{\gamma_1} + (1 - \alpha - \rho)\frac{\alpha + \gamma_0}{\gamma_0}\right]\psi.$$

Proof. See the Appendix.

Observe that it is optimal for the principal not to make a payment to the agent when the second stage was not successful, regardless of the outcome of the first stage ($w_{00} = w_{10} = 0$). Clearly, the principal does not want to reward the agent for a failure. However, a second-stage success is rewarded even if the first stage was a failure ($w_{01} > 0$). This is necessary in order to induce the agent to work hard in the second stage, even when he was not successful in the first stage (the second-stage incentive compatibility constraint conditional on a first-stage failure is always binding). With regard to the bonus w_{11} that is paid when both stages are successful, a case distinction has to be made.[11] Case (i) always applies if the tasks are synergistic ($\gamma_1 > \gamma_0$), and it also applies if a conflict between the tasks is not too strong. It turns out that the second-stage incentive compatibility constraint conditional on a first-stage success then is not binding; i.e., the wage scheme that motivates the agent to work hard in the first stage is sufficient to also motivate him to work hard in the second stage after a first-stage success. If the conflict is very strong, $\gamma_1 - \gamma_0$ may be

[11] Note that the assumptions that we made (to ensure that all expressions describing probabilities lie between zero and one) allow $\gamma_0\gamma_1 + (\gamma_1 - \gamma_0)\alpha\rho$ to be positive or negative.

so negative that we are in case (ii). In this case, it is very difficult to motivate the agent to work hard in the second stage following a first-stage success, so that the corresponding incentive compatibility constraint then is binding.

Suppose now that the principal has hired two different agents for the two different tasks. Let agent A be in charge of task 1, while agent B is responsible for task 2. The incentive compatibility constraint ensuring that agent A chooses high effort in the first stage (given that agent B will be induced to exert high effort in the second stage) reads

$$\begin{aligned}
& (\alpha+\rho)[(\alpha+\gamma_1)w_{11}^A+(1-\alpha-\gamma_1)w_{10}^A] \\
& +(1-\alpha-\rho)[(\alpha+\gamma_0)w_{01}^A+(1-\alpha-\gamma_0)w_{00}^A]-\psi \\
\geq\ & \alpha[(\alpha+\gamma_1)w_{11}^A+(1-\alpha-\gamma_1)w_{10}^A] \\
& +(1-\alpha)[(\alpha+\gamma_0)w_{01}^A+(1-\alpha-\gamma_0)w_{00}^A].
\end{aligned}$$

The incentive compatibility constraints that ensure that agent B chooses high effort in the second stage are

$$(\alpha+\gamma_1)w_{11}^B+(1-\alpha-\gamma_1)w_{10}^B-\psi \geq \alpha w_{11}^B+(1-\alpha)w_{10}^B$$

for the case that the first stage was a success and

$$(\alpha+\gamma_0)w_{01}^B+(1-\alpha-\gamma_0)w_{00}^B-\psi \geq \alpha w_{01}^B+(1-\alpha)w_{00}^B$$

for the case that the first stage was a failure.

The principal designs wage schemes $(w_{00,}^A w_{10}^A, w_{01}^A, w_{11}^A)$ and $(w_{00,}^B w_{10}^B, w_{01}^B, w_{11}^B)$ in order to minimize her expected costs

$$\begin{aligned}
& (\alpha+\rho)[(\alpha+\gamma_1)(w_{11}^A+w_{11}^B)+(1-\alpha-\gamma_1)(w_{10}^A+w_{10}^B)] \\
& +(1-\alpha-\rho)[(\alpha+\gamma_0)(w_{01}^A+w_{01}^B)+(1-\alpha-\gamma_0)(w_{00}^A+w_{00}^B)]
\end{aligned}$$

subject to the incentive compatibility constraints and the limited liability constraints $w_{q_1q_2}^A \geq 0$ and $w_{q_1q_2}^B \geq 0$. Note that these constraints again imply that the participation constraints are satisfied.

Lemma 2 *Suppose the principal has hired two different agents to work on the two different tasks. It is optimal for the principal to offer the contracts* $w^A_{11} = w^A_{10} = \psi/\rho$, $w^A_{01} = w^A_{00} = 0$ *and* $w^B_{11} = \psi/\gamma_1$, $w^B_{01} = \psi/\gamma_0$, $w^B_{10} = w^B_{00} = 0$. *Then the principal's expected costs are*

$$(\alpha + \rho)\left[\frac{1}{\rho} + \frac{\alpha + \gamma_1}{\gamma_1} + (1 - \alpha - \rho)\frac{\alpha + \gamma_0}{\gamma_0}\right]\psi.$$

Proof. See the Appendix.

Observe that agent A is rewarded whenever the first stage is successful ($w^A_{11} = w^A_{10} > 0$) and agent B is rewarded whenever the second stage is successful ($w^B_{11} > 0$, $w^B_{01} > 0$), while the other wages are zero. All incentive compatibility constraints are binding. Note that the reward that agent B gets after a first-stage success ($w^B_{11} = \psi/\gamma_1$) is larger than the reward he gets after a first-stage failure ($w^B_{01} = \psi/\gamma_0$) whenever the tasks are conflicting ($\gamma_1 < \gamma_0$), and vice versa if the tasks are synergistic.

We can now compare the principal's expected costs that we have derived in Lemma 1 and Lemma 2 in order to determine when the principal is better off hiring one agent or two agents. Our main result can be stated as follows.

Proposition 1 *Consider the case of output externalities.*

(i) If the two tasks are conflicting ($\gamma_1 < \gamma_0$), then the principal prefers to hire one agent who is in charge of both tasks.

(ii) If the two tasks are synergistic ($\gamma_1 > \gamma_0$), then the principal prefers to hire two different agents for the two different tasks.

(iii) If the two tasks are independent ($\gamma_1 = \gamma_0$), then the principal is indifferent between hiring one or two agents.

Proof. See the Appendix.

Intuitively, consider the case of conflicting tasks, so that a success in the first stage implies that it becomes more difficult to be successful in the second task. Hence, when the outcome of the first stage was a success, then the agent in charge of the second stage must get a larger rent in order to motivate him to exert high second-stage effort. For this reason, if the same agent is in charge of both stages, there is an additional incentive for him to exert high effort in the first stage (since high first-stage effort increases the probability that he will get a larger rent in the second stage). In contrast, consider the case of synergistic tasks. If the outcome of the first stage was a success, then the principal has to pay only a relatively small rent to the agent in charge of the second stage in order to induce high second-stage effort. If the same agent were in charge of both stages, it would thus be more difficult to motivate him to work hard in the first stage (since by shirking in the first stage he can increase the probability that he will get a larger rent in the second stage).

4 Effort externalities

We now briefly consider a model in which the tasks still have to be performed sequentially, but instead of an outcome externality as in the main part of the present paper, there is an effort externality as in Bolton and Dewatripont (2005).

Specifically, consider the following modification of our basic model. While the probability of a first-stage success is still given by $\Pr\{q_1 = 1\} = \alpha + \rho e_1$, the probability of a second-stage success is now given by $\Pr\{q_2 = 1\} = \alpha + \rho e_2 - \gamma e_1$, regardless of the first-stage outcome. Hence, the tasks are now conflicting if $\gamma > 0$, while they are synergistic if $\gamma < 0$. In line with Bolton and Dewatripont (2005), we assume that in the second stage the effect of first-stage effort is smaller than the effect of second-stage effort, $|\gamma| < \rho$, and that $\max\{\gamma, 0\} < \alpha < 1 - \rho + \min\{\gamma, 0\}$, so that the expressions describing probabilities lie between zero and one.

Suppose the principal has hired one agent. The principal's problem is to find non-negative wages $(w_{00,} w_{10}, w_{01}, w_{11})$ that minimize her expected costs

$$(\alpha+\rho)[(\alpha+\rho-\gamma)w_{11}+(1-\alpha-\rho+\gamma)w_{10}]+(1-\alpha-\rho)[(\alpha+\rho-\gamma)w_{01}+(1-\alpha-\rho+\gamma)w_{00}].$$

The second-stage incentive compatibility constraints are $\rho(w_{11} - w_{10}) \geq \psi$ for the case that the first stage was a success and $\rho(w_{01} - w_{00}) \geq \psi$ for the case that the first stage was a failure. The agent is willing to exert high effort in the first stage if the incentive compatibility constraint

$$\begin{aligned}
&(\alpha+\rho)[(\alpha+\rho-\gamma)w_{11} + (1-\alpha-\rho+\gamma)w_{10} - \psi] \\
&+(1-\alpha-\rho)[(\alpha+\rho-\gamma)w_{01} + (1-\alpha-\rho+\gamma)w_{00} - \psi] - \psi \\
\geq\ &\alpha[(\alpha+\rho)w_{11} + (1-\alpha-\rho)w_{10} - \psi] \\
&+(1-\alpha)[(\alpha+\rho)w_{01} + (1-\alpha-\rho)w_{00} - \psi]
\end{aligned}$$

is satisfied. Hence, the following result must hold.

Lemma 3 *Consider effort externalities and suppose the principal has delegated both tasks to one agent.*

(i) If $\gamma \leq 0$, it is optimal for the principal to offer the contract $w_{00} = w_{10} = 0$, $w_{01} = \psi/\rho$, and

$$w_{11} = \frac{\rho + (\alpha+\rho)(\rho-\gamma) + \gamma}{(\alpha+\rho)(\rho-\gamma)\rho}\psi.$$

Then her expected costs are $2[1 + \alpha/(\rho-\gamma)]\psi$.

(ii) If $\gamma > 0$, the principal will offer the contract $w_{00} = 0$, $w_{10} = (\gamma+\rho)\psi/\rho^2$, $w_{01} = \psi/\rho$, and $w_{11} = (\gamma+2\rho)\psi/\rho^2$. Then her expected costs are $[2 + (2\rho + \gamma)\alpha/\rho^2]\psi$.

Proof. See the Appendix.

Note that in the case of synergistic tasks, the agent does not get a reward if the second task fails. In contrast, in the case of conflicting tasks, when there was a first-stage success the agent even gets a reward if the second task is a failure. Intuitively, in the case of conflict, a failure in the second stage is indicative of high effort in the first stage. Moreover, note that the principal must always pay a positive wage when there is a second-stage success even when the first stage was a failure, because otherwise the agent would shirk in the second stage if the first stage was not successful.[12]

[12] Notice that this observation is different from the simultaneous choice setting in Bolton

Suppose now that the principal has hired two different agents, so that agent A is in charge of task 1 and agent B is in charge of task 2. The principal designs non-negative wages $(w^A_{00,}w^A_{10},w^A_{01},w^A_{11})$ and $(w^B_{00,}w^B_{10},w^B_{01},w^B_{11})$ in order to minimize her expected costs

$$\begin{aligned}&(\alpha+\rho)[(\alpha+\rho-\gamma)(w^A_{11}+w^B_{11})+(1-\alpha-\rho+\gamma)(w^A_{10}+w^B_{10})]\\&+(1-\alpha-\rho)[(\alpha+\rho-\gamma)(w^A_{01}+w^B_{01})+(1-\alpha-\rho+\gamma)(w^A_{00}+w^B_{00})].\end{aligned}$$

The incentive compatibility constraint ensuring that agent A chooses high effort in the first stage (given that agent B will be induced to exert high effort in the second stage) can be written as

$$\begin{aligned}&(\alpha+\rho)\,(\rho-\gamma)\,w^A_{11}+((1-\alpha-\rho)\,\rho+\gamma(\alpha+\rho))\,w^A_{10}\\&-((\alpha+\rho)(\rho-\gamma)+\gamma)\,w^A_{01}-(1-\alpha-\rho)\,(\rho-\gamma)\,w^A_{00}\geq\psi.\end{aligned}$$

The incentive compatibility constraints which ensure that agent B chooses high effort in the second stage are $\rho(w^B_{11}-w^B_{10})\geq\psi$ and $\rho(w^B_{01}-w^B_{00})\geq\psi$. Thus, we obtain the following result.

Lemma 4 *Consider effort externalities and suppose the principal has hired two different agents to work on the two different tasks. The principal sets* $w^B_{00}=w^B_{10}=0$ *and* $w^B_{11}=w^B_{01}=\psi/\rho$.

(i) If $\gamma\leq 0$*, it is optimal for the principal to set* $w^A_{00}=w^A_{01}=w^A_{10}=0$*, and* $w_{11}=\psi/[(\alpha+\rho)\,(\rho-\gamma)]$*. Then her expected costs are*

$$\frac{(2\rho-\gamma)\,(\alpha+\rho-\gamma)}{(\rho-\gamma)\,\rho}\psi.$$

(ii) If $\gamma>0$*, the principal will set* $w^A_{00}=w^A_{01}=w^A_{11}=0$*, and* $w^A_{10}=\psi/[(1-\alpha-\rho)\,\rho+\gamma(\alpha+\rho)]$*. Then her expected costs are*

$$\left[\frac{\alpha+\rho-\gamma}{\rho}+\frac{(1-\alpha-\rho+\gamma)(\alpha+\rho)}{(1-\alpha-\rho)\,\rho+(\alpha+\rho)\gamma}\right]\psi.$$

and Dewatripont (2005), in which it is possible to induce high efforts in both tasks by paying a positive wage if and only if both tasks are successful. This is not possible in our model, where the first-stage outcome is known when the second-stage effort level is chosen.

Proof. See the Appendix.

Observe that agent B must get a reward for a second-stage success regardless of the outcome of the first stage to motivate him to always exert high effort. However, in the case of synergistic tasks, agent A gets a reward only if both tasks are successful, while in the case of conflicting tasks, agent A gets a reward only if task 1 is a success and task 2 is a failure (since in the latter case a failure of task 2 is indicative of high effort in task 1).

Proposition 2 *Consider the case of effort externalities.*

(i) If the two tasks are conflicting ($\gamma > 0$), then the principal prefers to hire two different agents for the two different tasks.

(ii) If the two tasks are synergistic ($\gamma < 0$), then the principal prefers to hire one agent who is in charge of both tasks.

(iii) If the two tasks are independent ($\gamma = 0$), then the principal is indifferent between hiring one or two agents.

Proof. See the Appendix.

Proposition 2 shows that in a model with effort externalities, the insights of Dewatripont and Tirole (1999) and Bolton and Dewatripont (2005) are qualitatively robust also when the tasks are performed sequentially. The principal prefers to hire two different agents when the tasks are conflicting because it is difficult to motivate an agent to work hard on one task when this reduces the success probability of the other task.[13] Specifically, a success in task 2 may indicate that the agent worked hard in the second stage, but it might

[13]Note that in the simultaneous setting of Bolton and Dewatripont (2005), the principal prefers to hire two agents only if the conflict between the tasks is sufficiently strong, while she strictly prefers to hire one agent when the tasks are independent. In contrast, in the sequential model the principal prefers two agents whenever the tasks are conflicting. The reason is that as has been pointed out in footnote 12, in the simultaneous setting the principal can save rents by hiring one agent and paying him a positive wage if and only if both tasks are successful, which does not work in the sequential setting. As a consequence, hiring one agent has an additional advantage in the simultaneous setting.

also indicate that he shirked in the first stage. In contrast, in the model with outcome externalities analyzed in the main part of the paper, given the first-stage outcome, the outcome of stage 2 could not be indicative of the effort level chosen in stage 1. Taken together, when a principal has to decide whether to delegate two sequential tasks to one agent or to two agents, it is of crucial importance whether the second stage is influenced by the first-stage effort or by the first-stage outcome.

5 Concluding remarks

When a principal wants to induce high efforts in two sequential tasks, then for incentive reasons she may be better off hiring one agent if the tasks are in conflict, while she may prefer to hire two different agents if there are synergies between the tasks. This result holds when there is an outcome externality; i.e., when the outcome of the first stage can make it more or less difficult to be successful in the second stage. In contrast, when there is an effort externality, so that first-stage effort has a direct impact on the second-stage success probability, then the opposite result holds.

Several avenues for future research seem to be promising. The model was kept as simple as possible to highlight the effects in a clear way. In future work, the model could be extended to cover also adverse selection aspects, where agents have private information about their types.[14] The interaction of limited liability rents and information rents can be complicated (see Laffont and Martimort, 2002), but might lead to interesting new insights. Moreover, since the model is very simple, it might be useful as a building block in more applied work. For instance, the first and second stage could correspond to different levels of a supply chain, so that when the same decision-maker is

[14] Models analyzing task assignment and job design from an adverse selection perspective include Riordan and Sappington (1987), Dana (1993), Gilbert and Riordan (1995), and Lewis and Sappington (1997).

in charge of both stages, there would be vertical integration according to the traditional definition in the industrial organization literature.[15] Moreover, the question whether or not there should be term limits for politicians (cf. Besley and Case, 1995) is closely related to the question whether or not the same agent should be in charge of sequential tasks. Furthermore, starting with Hart (2003) and Bennett and Iossa (2006), several authors have recently pointed out that an important characteristic of so-called public-private partnerships is that the two stages of building and subsequently managing a public facility are delegated to one agent (a consortium), while under traditional procurement the two sequential tasks of building and managing are delegated to two different contractors. While the relevance of both positive and negative externalities between the stages is also a common theme in this applied literature,[16] the effects of conflicting tasks in a moral hazard framework as analyzed in the present paper have not yet been considered there. Integrating these kinds of externalities might lead to interesting novel insights.

[15] See Tirole (1988, ch. 4) and cf. Grossman and Hart (1986), Hart and Moore (1990), and Hart (1995) for an incomplete contracting perspective on vertical integration.

[16] See Martimort and Pouyet (2008), Chen and Chiu (2010, 2011), De Brux and Desrieux (2011), Iossa and Martimort (2012), Hoppe and Schmitz (2012), and Martimort and Straub (2012). See also the related theoretical studies on privatization by Hart, Shleifer, and Vishny (1997) and Hoppe and Schmitz (2010).

Appendix

Proof of Lemma 1.

Note that the incentive compatibility constraints can be rewritten such that they read $\gamma_1(w_{11} - w_{10}) \geq \psi$ and $\gamma_0(w_{01} - w_{00}) \geq \psi$ in the second stage, and

$$\rho[(\alpha + \gamma_1)w_{11} + (1 - \alpha - \gamma_1)w_{10} - (\alpha + \gamma_0)w_{01} - (1 - \alpha - \gamma_0)w_{00}] \geq \psi$$

in the first stage. Observe first that $w_{00} = 0$ must hold in the solution to the principal's problem.[17] Hence, the incentive compatibility constraint for the second stage after a first-stage failure now reads $\gamma_0 w_{01} \geq \psi$. Note that in the optimum this constraint must be binding, $w_{01} = \psi/\gamma_0$. The first-stage incentive compatibility constraint can thus be rewritten as

$$\rho[w_{10} + (\alpha + \gamma_1)(w_{11} - w_{10}) - (\alpha + \gamma_0)\psi/\gamma_0] \geq \psi.$$

(i) Ignore for a moment the second-stage incentive compatibility constraint conditional on a first-stage success, $\gamma_1(w_{11} - w_{10}) \geq \psi$. Then the binding first-stage incentive compatibility constraint implies

$$w_{11} = w_{10} + \frac{\psi/\rho + (\alpha + \gamma_0)\psi/\gamma_0 - w_{10}}{\alpha + \gamma_1}.$$

The omitted constraint $\gamma_1(w_{11} - w_{10}) \geq \psi$ is thus satisfied whenever

$$w_{10} \leq \frac{\gamma_0\gamma_1 + (\gamma_1 - \gamma_0)\alpha\rho}{\rho\gamma_0\gamma_1}\psi.$$

Hence, we have found the solution in the case $\gamma_0\gamma_1 + (\gamma_1 - \gamma_0)\alpha\rho \geq 0$. Note that the principal has some freedom in choosing w_{11} and w_{10} when $\gamma_0\gamma_1 + (\gamma_1 - \gamma_0)\alpha\rho > 0$, since there are multiple combinations of these two wages leading to the (uniquely determined) minimal expected costs $[(\alpha + \rho)/\rho + (\alpha + \gamma_0)/\gamma_0]\psi$. Specifically, the principal can always set $w_{10} = 0$ and

$$w_{11} = \psi\frac{\gamma_0 + \rho(\alpha + \gamma_0)}{\rho\gamma_0(\alpha + \gamma_1)},$$

[17] To see this, assume that in the solution $w_{00} > 0$ would hold. Then the principal's expected profit could be increased by reducing w_{00} without violating any constraints, contradicting the optimality of $w_{00} > 0$.

as stated in the lemma.

(ii) Next consider the case $\gamma_0\gamma_1 + (\gamma_1 - \gamma_0)\alpha\rho < 0$, so that the constraint $\gamma_1(w_{11} - w_{10}) \geq \psi$ must be binding. Hence, $w_{11} = \psi/\gamma_1 + w_{10}$. The first-stage incentive compatibility constraint is then satisfied whenever

$$w_{10} \geq \psi \left(\frac{1}{\rho} - \frac{\alpha + \gamma_1}{\gamma_1} + \frac{\alpha + \gamma_0}{\gamma_0} \right).$$

The right-hand side of this constraint is negative, since $\gamma_0\gamma_1 + (\gamma_1 - \gamma_0)\alpha\rho < 0$. Thus, the condition is always satisfied when the principal sets w_{10} as small as possible, $w_{10} = 0$. Therefore, if $\gamma_0\gamma_1 + (\gamma_1 - \gamma_0)\alpha\rho < 0$, the principal sets $w_{11} = \psi/\gamma_1$ and her expected costs are given by

$$\left[(\alpha + \rho)\frac{\alpha + \gamma_1}{\gamma_1} + (1 - \alpha - \rho)\frac{\alpha + \gamma_0}{\gamma_0} \right] \psi.$$

■

Proof of Lemma 2.

It is easy to see that agent A's incentive compatibility constraint can be simplified to

$$\rho[(\alpha + \gamma_1)w_{11}^A + (1 - \alpha - \gamma_1)w_{10}^A - (\alpha + \gamma_0)w_{01}^A - (1 - \alpha - \gamma_0)w_{00}^A] \geq \psi.$$

Moreover, agent B's incentive compatibility constraints can be rewritten as $\gamma_1(w_{11}^B - w_{10}^B) \geq \psi$ and $\gamma_0(w_{01}^B - w_{00}^B) \geq \psi$. Hence, the principal will set $w_{00}^B = w_{10}^B = 0$, so that the binding constraints imply $w_{11}^B = \psi/\gamma_1$ and $w_{01}^B = \psi/\gamma_0$.

With regard to agent A, the principal has to set $w_{00}^A = w_{01}^A = 0$ in order to minimize her expected costs. The principal has some freedom in designing the wages w_{11}^A and w_{10}^A. All combinations of w_{11}^A and w_{10}^A that satisfy agent A's binding incentive compatibility constraint

$$(\alpha + \gamma_1)w_{11}^A + (1 - \alpha - \gamma_1)w_{10}^A = \psi/\rho$$

minimize the principal's expected costs. Specifically, it seems to make sense not to condition agent A's wages on the outcome of the second stage, $w_{11}^A = w_{10}^A =$

ψ/ρ. In any case, the principal's expected costs are uniquely determined; they are given by

$$(\alpha+\rho)\left[\frac{1}{\rho}+\frac{\alpha+\gamma_1}{\gamma_1}+(1-\alpha-\rho)\frac{\alpha+\gamma_0}{\gamma_0}\right]\psi.$$

■

Proof of Proposition 1.

Consider first the case $\gamma_0\gamma_1+(\gamma_1-\gamma_0)\alpha\rho\geq 0$. Inspection of Lemma 1 and Lemma 2 immediately reveals that the principal prefers to hire only one agent in charge of both tasks whenever

$$\begin{aligned}&\left[\frac{\alpha+\rho}{\rho}+\frac{\alpha+\gamma_0}{\gamma_0}\right]\psi\\ \leq\ &(\alpha+\rho)\left[\frac{1}{\rho}+\frac{\alpha+\gamma_1}{\gamma_1}+(1-\alpha-\rho)\frac{\alpha+\gamma_0}{\gamma_0}\right]\psi,\end{aligned}$$

which is equivalent to

$$(\alpha+\gamma_0)\gamma_1\leq(\alpha+\rho)(\alpha+\gamma_1)\gamma_0+(1-\alpha-\rho)(\alpha+\gamma_0)\gamma_1$$

and which can be further simplified to $\gamma_1\leq\gamma_0$. Hence, the principal prefers to hire one agent (two agents) whenever the two tasks are conflicting (synergistic).

Next, consider the case $\gamma_0\gamma_1+(\gamma_1-\gamma_0)\alpha\rho<0$. Note that this case can occur only if the tasks are conflicting ($\gamma_1<\gamma_0$). In this case, it follows from Lemma 1 and Lemma 2 that the principal prefers to hire only one agent in charge of both tasks whenever

$$\begin{aligned}&\left[(\alpha+\rho)\frac{\alpha+\gamma_1}{\gamma_1}+(1-\alpha-\rho)\frac{\alpha+\gamma_0}{\gamma_0}\right]\psi\\ \leq\ &(\alpha+\rho)\left[\frac{1}{\rho}+\frac{\alpha+\gamma_1}{\gamma_1}+(1-\alpha-\rho)\frac{\alpha+\gamma_0}{\gamma_0}\right]\psi.\end{aligned}$$

This condition can be rewritten as $0\leq(\alpha+\rho)/\rho$, which is always satisfied. Hence, the proposition follows immediately. ■

Proof of Lemma 3.

It is straightforward to see that the principal will set $w_{00} = 0$. Hence, she minimizes

$$(\alpha+\rho)[(\alpha+\rho-\gamma)w_{11} + (1-\alpha-\rho+\gamma)w_{10}] + (1-\alpha-\rho)(\alpha+\rho-\gamma)w_{01}$$

subject to the second-stage incentive compatibility constraints $\rho(w_{11} - w_{10}) \geq \psi$ and $\rho w_{01} \geq \psi$, the first-stage incentive compatibility constraint

$$\begin{aligned}&(\alpha+\rho)(\rho-\gamma)\,w_{11} + [(1-\alpha-\rho)\,\rho + \gamma(\alpha+\rho)]w_{10} \\ &- [(\alpha+\rho)(\rho-\gamma)+\gamma]w_{01} \geq \psi,\end{aligned}$$

and the limited liability constraints. It is easy to verify that it is optimal for the principal to set $w_{01} = \psi/\rho$.

Suppose that

$$(1-\alpha-\rho)\,\rho + \gamma(\alpha+\rho) \leq 0,$$

so that $\gamma < 0$. Then the principal sets $w_{10} = 0$, so that the first-stage incentive compatibility constraint is binding and thus

$$w_{11} = \frac{\rho + (\alpha+\rho)(\rho-\gamma)+\gamma}{(\alpha+\rho)(\rho-\gamma)\,\rho}\psi.$$

In this case, the constraint $\rho(w_{11} - w_{10}) \geq \psi$ is non-binding and the principal's expected costs are $2[1+\alpha/(\rho-\gamma)]\psi$. Now suppose that

$$(1-\alpha-\rho)\,\rho + \gamma(\alpha+\rho) > 0.$$

Note that if in the solution $w_{10} > 0$, then all incentive compatibility constraints must be binding, so that $w_{10} = (\gamma+\rho)\,\psi/\rho^2$ and $w_{11} = (\gamma+2\rho)\,\psi/\rho^2$, and the principal's expected costs are $[2+(2\rho+\gamma)\alpha/\rho^2]\psi$. The latter expression is smaller than $2[1+\alpha/(\rho-\gamma)]\psi$ whenever γ is positive. The lemma then follows immediately. ■

Proof of Lemma 4.

Observe that it is optimal for the principal to set $w_{00}^A = w_{01}^A = w_{00}^B = w_{10}^B = 0$ and $w_{11}^B = w_{01}^B = \psi/\rho$. Agent A's incentive compatibility constraint reads

$$(\alpha+\rho)\,(\rho-\gamma)\,w_{11}^A + ((1-\alpha-\rho)\,\rho+\gamma(\alpha+\rho))\,w_{10}^A \geq \psi.$$

Suppose

$$(1-\alpha-\rho)\,\rho+\gamma(\alpha+\rho) \leq 0,$$

so that $\gamma < 0$. Then the principal sets $w_{10}^A = 0$ and thus $w_{11}^A = \psi/[(\alpha+\rho)\,(\rho-\gamma)]$. Next, suppose

$$(1-\alpha-\rho)\,\rho+\gamma(\alpha+\rho) > 0.$$

It is straightforward to check that the principal will then set $w_{11}^A = 0$ and $w_{10}^A = \psi/[(1-\alpha-\rho)\,\rho+\gamma(\alpha+\rho)]$ if γ is positive, while she sets $w_{10}^A = 0$ and thus $w_{11}^A = \psi/[(\alpha+\rho)\,(\rho-\gamma)]$ if γ is negative. The lemma follows immediately. ■

Proof of Proposition 2.

(i) Suppose $\gamma > 0$. The principal's expected costs if she hires one agent are $K_1 := [2+(2\rho+\gamma)\alpha/\rho^2]\psi$, while her expected costs if she hires two agents are

$$K_2 := \left[\frac{\alpha+\rho-\gamma}{\rho} + \frac{(1-\alpha-\rho+\gamma)(\alpha+\rho)}{(1-\alpha-\rho)\,\rho+(\alpha+\rho)\gamma}\right]\psi.$$

It is straightforward to check that

$$K_1 = \frac{2\rho^2+(2\rho+\gamma)\alpha}{\rho^2}\psi$$

and

$$K_2 = \frac{(\alpha+\rho-\gamma)[(1-\alpha-\rho)\,\rho+(\alpha+\rho)\gamma]+(1-\alpha-\rho+\gamma)(\alpha+\rho)\rho}{\rho[(1-\alpha-\rho)\,\rho+(\alpha+\rho)\gamma]}\psi.$$

Hence, the difference in expected costs is

$$K_1 - K_2 = \gamma\frac{\psi}{\rho^2}\,(\alpha+\rho)\,\frac{(1-\rho)\,\rho+(\alpha+\rho)\gamma}{(1-\rho-\alpha)\,\rho+(\alpha+\rho)\gamma},$$

which under our assumptions is strictly positive.

(ii) Suppose $\gamma < 0$. The principal's expected costs if she hires one agent are $K_1 := 2[1 + \alpha/(\rho - \gamma)]\psi$, while her expected costs if she hires two agents are

$$K_2 := \frac{(2\rho - \gamma)(\alpha + \rho - \gamma)}{(\rho - \gamma)\rho}\psi.$$

Thus, the difference in expected costs is

$$K_2 - K_1 = -\gamma \frac{\psi}{\rho(\rho - \gamma)}(\alpha - \gamma + \rho),$$

which under our assumptions is strictly positive.

(iii) Suppose $\gamma = 0$. Then the principal's expected costs are $2\psi(\alpha + \rho)/\rho$, regardless of whether she hires one or two agents. ■

References

Bennett, J., Iossa, E., 2006. Building and managing facilities for public services. Journal of Public Economics 90, 2143–2160.

Berkovitch, E., Israel, R., Spiegel, Y., 2010. A double moral hazard model of organization design. Journal of Economics and Management Strategy 19, 55–85.

Besley, T., Case, A., 1995. Does electoral accountability affect economic policy choices? Evidence from gubernatorial term limits. Quarterly Journal of Economics 110, 769–798.

Bolton, P., Dewatripont, M., 2005. Contract Theory. Cambridge, MA: MIT Press.

Chen, B.R., Chiu, Y.S., 2010. Public-private partnerships: Task interdependence and contractibility. International Journal of Industrial Organization 28, 591–603.

Chen, B.R., Chiu, Y.S., 2011. Task interdependence and non-contractibility in public good provision. Discussion Paper.

Dana, J.D., Jr., 1993. The organization and scope of agents: Regulating multiproduct industries. Journal of Economic Theory 59, 288–310.

De Brux, J., Desrieux, C., 2011. Should we fear renegotiations in public-private partnerships? Discussion Paper.

Dewatripont, M., Jewitt, I., Tirole, J., 2000. Multitask agency problems: Focus and task clustering. European Economic Review 44, 869–877.

Dewatripont, M., Tirole, J., 1999. Advocates. Journal of Political Economy 107, 1–39.

Gilbert, R.J., Riordan, M.H., 1995. Regulating complementary products: A comparative institutional analysis. Rand Journal of Economics 26, 243–256.

Grossman, S.J., Hart, O.D., 1986. The costs and benefits of ownership: A theory of vertical and lateral integration. Journal of Political Economy 94, 691–719.

Hart, O.D., 1995. Firms, Contracts and Financial Structure. Oxford: Oxford University Press.

Hart, O., 2003. Incomplete contracts and public ownership: Remarks, and an application to public-private partnerships. Economic Journal 113, C69–C76.

Hart, O.D., Moore, J., 1990. Property rights and the nature of the firm. Journal of Political Economy 98, 1119–1158.

Hart, O., Shleifer, A., Vishny, R.W., 1997. The proper scope of government: Theory and application to prisons. Quarterly Journal of Economics 112, 1127–1161.

Hirao, Y., 1993. Task assignment and agency structures. Journal of Economics and Management Strategy 2, 299–323.

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

Hoppe, E.I., Kusterer, D.J., 2011. Conflicting tasks and moral hazard: Theory and experimental evidence. European Economic Review 55, 1094–1108.

Hoppe, E.I., Schmitz, P.W., 2010. Public versus private ownership: Quantity contracts and the allocation of investment tasks. Journal of Public Economics 94, 258–268.

Hoppe, E.I., Schmitz, P.W., 2012. Public-private partnerships versus traditional procurement: Innovation incentives and information gathering. Rand Journal of Economics, forthcoming.

Innes, R.D., 1990. Limited liability and incentive contracting with ex-ante action choices. Journal of Economic Theory 52, 45–67.

Iossa, E., Martimort, D., 2012. Risk allocation and the costs and benefits of public-private partnerships. Rand Journal of Economics 43, 442–474.

Itoh, H., 1994. Job design, delegation and cooperation: A principal-agent analysis. European Economic Review 38, 691–700.

Khalil, F., Kim, D., Shin, D., 2006. Optimal task design: To integrate or separate planning and implementation? Journal of Economics and Management Strategy 15, 457–478.

Kragl, J., Schöttner, A., 2011. Wage floors and optimal job design. Discussion Paper.

Kräkel, M., Schöttner, A., 2010. Minimum wages and excessive effort supply. Economics Letters 108, 341–344.

Kräkel, M., Schöttner, A., 2011. Internal labor markets and worker rents. Discussion Paper.

Laffont, J.-J., Martimort, D. 2002. The Theory of Incentives: The Principal-Agent Model. Princeton, N.J.: Princeton University Press.

Lewis, T.R., Sappington, D.E.M., 1997. Information management in incentive problems. Journal of Political Economy 105, 796–821.

Martimort, D., Pouyet, J., 2008. To build or not to build: Normative and positive theories of public–private partnerships. International Journal of Industrial Organization 26, 393–411.

Martimort, D., Straub, S., 2012. How to design infrastructure contracts in a warming world? A critical appraisal of public-private partnerships. Discussion Paper.

Müller, D., 2011. Repeated moral hazard revisited. Discussion Paper.

Nieken, P., Schmitz, P.W., 2012. Repeated moral hazard and contracts with memory: A laboratory experiment. Games and Economic Behavior 75, 1000–1008.

Ohlendorf, S., Schmitz, P.W., 2012. Repeated moral hazard and contracts with memory: The case of risk-neutrality. International Economic Review 53, 433–452.

Pitchford, R., 1998. Moral hazard and limited liability: The real effects of contract bargaining. Economics Letters 61, 251–259.

Riordan, M.H., Sappington, D.E.M., 1987. Information, incentives, and organizational mode. Quarterly Journal of Economics 102, 243–263.

Schmitz, P.W., 2005. Allocating control in agency problems with limited liability and sequential hidden actions. Rand Journal of Economics 36, 318–336.

Tirole, J., 1988. The Theory of Industrial Organization. Cambridge: MIT Press.

Tirole, J., 1999. Incomplete contracts: Where do we stand? Econometrica 67, 741–781.

Tirole, J., 2001. Corporate governance. Econometrica 69, 1–35.