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ABSTRACT

Should a principal hire one agent or two agents to perform two sequential tasks?

A principal should hire one agent to perform two sequential tasks when the tasks are conflicting (i.e., a first-stage success makes second-stage effort less effective), while she should hire two different agents when the tasks are synergistic.

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1 Introduction

In contract theory, there is by now a large literature on multitask principal-agent problems in the presence of moral hazard.[1] Starting with Holmström and Milgrom (1991), many contributions in this literature are focused on the trade-off between insurance and incentives when agents are risk-averse and a central role is played by the effort-substitution problem. However, as has been pointed out by Dewatripont and Tirole (1999) and Bolton and Dewatripont (2005, Sections 6.2.2 and 6.4), interesting multitask problems may also arise when agents are risk-neutral but wealth-constrained, even in the absence of an effort-substitution problem.[2] Specifically, when two tasks are to be performed simultaneously and when the tasks are in direct conflict, eliciting effort on both tasks from a single agent can be so expensive for a principal that hiring two different agents (i.e., one agent per task) becomes optimal. In contrast, if the two tasks are independent (or if there are even synergies between the tasks), the principal is better off when she hires only one agent.

In the present paper, a variant of Bolton and Dewatripont's (2005) model is studied in which two tasks are to be performed sequentially.[3] It turns out that then Bolton and Dewatripont's (2005) results may be overturned. Surprisingly, 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, so that a success in the first task makes effort in the second task more effective, then the principal prefers to hire two different agents for the

[1] For reviews of the literature, see Dewatripont, Jewitt, and Tirole (2000), Laffont and Martimort (2002, ch. 5), and Bolton and Dewatripont (2005, ch. 6).

[2] On moral hazard problems with risk-neutral but wealth-constrained agents, see also Innes (1990), Pitchford (1998), and Tirole (2001).

[3] On agency problems with sequential tasks, see also Hirao (1993), Schmitz (2005), and Khalil, Kim, and Shin (2006). Yet, these contributions do not consider the kind of conflicting tasks that are the focus of the present paper.

two different tasks.

Intuitively, 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. Hence, when the tasks are conflicting, an agent who is in charge in both stages is motivated to exert effort in the first stage (and thus make second-stage effort less effective) in order to 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 be tempted not to exert effort in the first stage (and thus make second-stage effort less effective) in order to increase his second-stage rent.

2 The model

Consider a principal who wants two sequential tasks to be performed. The 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. Two different scenarios are considered. In scenario I, the principal employs a single agent to perform both tasks, while in scenario II, she employs two different agents for the two different tasks. All parties are risk neutral. An agent has no wealth and his reservation utility is zero. Effort on task $i \in \{1,2\}$ is denoted by $e_i \in \{0,1\}$. An agent who exerts 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. Note that the two tasks are technologically independent if $\gamma_1 = \gamma_0$. We say that the two tasks are *conflict-*

ing 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 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 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 in which of the two scenarios the principal's agency costs are smaller. To induce an agent to exert effort, the principal can offer him a wage scheme $w_{q_1q_2} := w(q_1, q_2) \geq 0$ that is contingent on the outcomes of both tasks.

2.1 Scenario I: One agent

Suppose first that the principal has hired only one agent to perform both tasks. The incentive compatibility constraints that ensure 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 ($q_1 = 0$). In the first stage, the incentive compatibility constraint reads

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

The principal's problem is 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 satisfied.

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

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

Hence, it is straightforward to prove the following result.[4]

Proposition 1 *Given that the principal has delegated both tasks to one agent, it is optimal for her to offer the contract* $w_{00} = w_{10} = 0$, $w_{01} = \psi/\gamma_0$, *and* $w_{11} = \psi[\gamma_0 + \rho(\alpha+\gamma_0)]/[\rho\gamma_0(\alpha+\gamma_1)]$. *Then the principal's expected costs are* $[(\alpha+\rho)/\rho + (\alpha+\gamma_0)/\gamma_0]\psi$.

2.2 Scenario II: Two agents

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 (given that agent B will be induced to exert high effort) is

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

[4]Note that the principal's expected costs are uniquely determined, while the principal has some freedom in setting w_{10} and w_{11}. To obtain the given expression for w_{11}, note that when $w_{10} = 0$, then the incentive compatibility constraints imply that w_{11} must be weakly larger than $\psi \max\{1/\gamma_1, 1/[\rho(\alpha+\gamma_1)] + (\alpha+\gamma_0)/[\gamma_0(\alpha+\gamma_1)]\} = \psi[\gamma_0+\rho(\alpha+\gamma_0)]/[\rho\gamma_0(\alpha+\gamma_1)]$.

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 in order to minimize her expected costs

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

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.

It is easy to see that the incentive compatibility constraints can be simplified to

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

$\gamma_1(w_{11}^B-w_{10}^B)\geq\psi$, and $\gamma_0(w_{01}^B-w_{00}^B)\geq\psi$. Thus, it is straightforward to see that the following result must hold.[5]

Proposition 2 *Given that the principal has hired two different agents to work on the two different tasks, it is optimal for her to offer the contracts* $w_{11}^A=w_{10}^A=\psi/\rho$, $w_{01}^A=w_{00}^A=0$ *and* $w_{11}^B=\psi/\gamma_1$, $w_{01}^B=\psi/\gamma_0$, $w_{10}^B=w_{00}^B=0$. *Then the principal's expected costs are* $(\alpha+\rho)[\psi/\rho+(\alpha+\gamma_1)\psi/\gamma_1]+(1-\alpha-\rho)[(\alpha+\gamma_0)\psi/\gamma_0]$.

[5] Note again that the principal has some freedom in designing the actual wages. Specifically, it seems to make sense not to condition agent A's wages on the outcome of the second stage. In any case, the principal's expected costs are uniquely determined.

2.3 One agent or two agents?

We can now compare the principal's expected costs in the two scenarios. Inspection of Propositions 1 and 2 immediately reveals that the principal prefers to hire only one agent in charge of both tasks whenever

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

which can be rewritten as $\gamma_1 \leq \gamma_0$. Our main result can thus be stated as follows.

Proposition 3 *(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.

3 Concluding remarks

When agents are risk-neutral but wealth-constrained and 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. These somewhat surprising results are in contrast to the findings of Bolton and Dewatripont (2005), who consider a framework where tasks are to be performed simultaneously. Two avenues for future research seem to be promising.

First, since the model outlined is very simple, it might be useful as a building block in more applied work. In particular, starting with Hart (2003) and Bennett and Iossa (2006), several authors have recently pointed out that an important characteristic of 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 positive and negative externalities between the stages is also a common theme in this applied literature,[6] the effects of conflicting tasks as analyzed in the present paper have not yet been considered there. Integrating these kinds of externalities might lead to interesting novel insights that so far have escaped the literature on public-private partnerships.

Second, Hoppe and Kusterer (2010) have recently extended Bolton and Dewatripont's (2005) analysis of the simultaneous tasks framework and they have conducted a laboratory experiment which shows that the theoretically predicted incentive problems due to conflicting tasks are indeed corroborated by the data. Thus, it may be an interesting topic for future research to also conduct an experiment in which the tasks are to be performed sequentially as in the present setup and to investigate whether the trade-offs highlighted in the present paper also have predictive power in the laboratory.

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[6] See also Iossa and Martimort (2008), Chen and Chiu (2009), and Hoppe and Schmitz (2010).

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