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Delegating Investment in a Common-Value Project

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This paper originated as "Optimal R&D Incentives: Why Patents?", which gave an example suggesting the results. My coauthor Jacques Cremer has dropped out due to other commitments, but I thank him for his contributions, as well as seminar participants at the UBC Summer IO workshop 1997, the Berkeley-Stanford IOFest 1997, the AEA meetings 1997, and CERAS 1998. This work was supported by the National Science Foundation, grant 97-09204.

Abstract E99-266

I investigate the problem of delegating an investment effort when it is not known in advance which firm is most efficient, or whether the investment should be made at all. The motivating problem is that of commissioning R&D instead of relying on patent incentives. Firms have different private signals of a project's private (and social) value, and different costs of achieving it. I show that the two allocation problems of (i) making an efficient decision whether to invest, and (ii) delegating the investment to the least-cost firm can simultaneously be solved with no more profit dissipation than a procurement mechanism would require, assuming that the signals of value were known in advance.

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1 Introduction

I investigate the problem of delegating an investment effort when it is not known in advance which firm is most efficient, or whether the investment should be made at all. The motivating problem is that of commissioning research. Firms will typically have different private signals of a project's value, and different costs of achieving it. Two allocation problems must be solved, both of which require that the firms' information be aggregated: First, there must be an *efficient decision* whether to invest in the project, and second, the investment effort must be *delegated* to the most efficient firm.

The example I think of as canonical is this: One firm has a high signal of the project's value, but cannot achieve the innovation at reasonable cost. Another firm has a weaker signal of value, but can achieve the innovation at lower cost. The first-best (full information) outcome could be that the low-cost firm should invest based on information possessed by the high-cost firm. However if the firms have no way to aggregate their information, then it might be that neither firm invests. The high-cost firm is dissuaded by his high cost, and the low-cost firm is dissuaded by his low signal of value. I investigate the degree to which optimal mechanisms can overcome this problem.

This is a problem that arises under patent incentives. A common justification for patents is that firms have better information on both the value and costs of innovation than a patent authority has, and investment decisions should therefore be delegated to them. Except possibly when there is only one potential innovator (see Scotchmer 1999), such a justification does not hold up. There is no guarantee that the most efficient firms will invest in R&D, and there is no guarantee that their aggregate information on the value of the investment will be shared by observing each other's investment decisions (see Minehart and Scotchmer 1999).

There has been surprisingly little investigation into optimal mechanisms to solve these problems. Most studies of R&D incentives take patent incentives as given, and study their consequences. An early departure from that agenda was by Wright (1983), who compared patents to other second-best incentive schemes (prizes and contracts), but did not try to characterize the best mechanism in a more general sense. Gandal and Scotchmer (1993) showed how firms could use optimal mechanisms to delegate effort to the most efficient firms. In another departure from patent incentives, Kremer (1998) proposed that the government buy the patent ex post, paying the firm an amount linked to the social value of the innovation, and putting the patent in the public domain. The buyout is a remedy to inefficient monopoly pricing, but cannot solve ex ante inefficiencies such as delegating to the most efficient firm. The mechanism proposed below is conducted ex ante rather than ex post, and thus has the advantage of efficient delegation. In addition, it remunerates firms based on their R&D cost, rather than on the social value of the innovation, which can be much greater. Since the mechanism avoids patents entirely, there is no ex post problem of reducing monopoly distortions.

Other mechanism design papers that use ex ante information, but not additional information that is verifiable ex post, include Cornelli and Schankerman (1999), Scotchmer (1999), Hopenhayn and Mitchell (1999). Like Kremer, they investigate research environments with only one innovator, and thus do not address the problems of delegating to an efficient firm or aggregating firms' information on value.

It is the conjunction of the decision problem and delegation problem that makes it unobvious what can be implemented. On one hand, if the value of the project is known, then the only problem is how to delegate efficiently. This problem has been solved for various cases in the procurement literature, e.g., Sappington (1982), Laffont and Tirole (1986,1987). On the other hand, if the firms' costs are known, then the only problem is to aggregate information on value in order to make an efficient decision. My assumption in this paper is that the signals of value are correlated by a true, underlying value of the investment. It is known for auction models that correlated information can be aggregated costlessly (Cremer and McLean (1985,1988), see also McAfee and McMillan (1987) and McAfee, McMillan and Reny (1989)). I show how the underpinnings of Cremer and McLean (1988) can be used to solve the joint problems of information aggregation and efficient delegation. Firms are first asked to reveal their information on value, and then a procurement mechanism is used to delegate effort, assuming that the firms' revelations about value are truthful (as they will be). In this solution, no more rent is dissipated to firms than would be dissipated if the firms' valuations were observable. I then develop a simpler mechanism, the *squared-deviation mechanism*, which can alternatively be used in some cases of interest.

This paper can be interpreted as arguing that patents are an unnecessary part of an optimal screening mechanism, at least when there is more than one firm and their private signals of the project's value are correlated. As in auctions, the private correlated information can be elicited costlessly. However there are other justifications for patents as an incentive mechanism that are not discussed here. If only one firm is capable of the innovation, or if there is no correlation in the firms' information, then it is hard to elicit information on value ex ante. Patents are a means to do this (see Scotchmer 1999). Another justification (see Cornelli and Schankerman (1999) or Cremer and Scotchmer (1996) for a model similar to this one) is moral hazard. When the patent authority cannot contract on the firms' rates of investment, patent incentives can give endogenous incentives to invest.

2 A General Result

We contemplate investment in an R&D project with an unknown value. Let N be an index set of potential innovators and let M_i, $i \in N$, be the sets of possible signals of the project's value. Let $M = \prod_{i \in N} M_i$ and $M_{-i} = \prod_{j \neq i} M_j$. Thus, $v_i \in M_i$ is firm i's signal of value, and $v_{-i} \in M_{-i}$ is a vector of all the other firms' signals. The probability of each $v_i \in M_i$ is described by $\pi^i(v_i|v_{-i})$, and the probability of v_{-i}, conditional on v_i, is described by $\pi^{-i}(v_{-i}|v_i)$. Thus the private signals $\{v_i\}_{i \in N}$ are assumed to be correlated. We assume that the costs $\{c_i\}_{i \in N}$ are drawn independently from distributions f^i on sets $K_i \subset \mathbf{R}_+$ and let $K = \prod_{i \in N} K_i$, $K_{-i} = \prod_{j \in N \setminus i} K_j$. We let f^{-i} represent the joint distribution of the costs of firms other than i.

The following assumption on the distribution π is from Cremer and MacLean (1988), and the lemma, which follows from Farkas' Lemma, restates part of their argument. The assumption means that there is no signal v_i that is so redundant with the other signals $\nu_i \in M_i \backslash v_i$ that the conditional distribution of v_{-i} (conditional on v_i) is a convex sum of the distributions of v_{-i} conditional on the other signals $\nu_i \in M_i \backslash v_i$.

Assumption 1 *For all $i \in N$, there do not exist $v_i \in M_i$ and $\{\rho_i(\nu_i) \in \mathbf{R}_{++}\}_{\nu_i \in M_i \backslash v_i}$, such that*

$$\pi(v_{-i}|v_i) = \sum_{\nu_i \in M_i \backslash v_i} \rho_i(\nu_i)\pi(v_{-i}|\nu_i) \qquad \text{for all } v_{-i} \in M_{-i}$$

Lemma 1 (Cremer and McLean 1988) *If Assumption 1 holds, then there exist values $\{\tilde{t}_i(v_i, v_{-i}) \in \mathbf{R}\}_{(v_i, v_{-i}) \in M}$ for each $i \in N$ such that*

$$\sum_{v_{-i} \in M_{-i}} \tilde{t}_i(v_i, v_{-i})\pi(v_{-i}|v_i) = 0 \qquad \text{for each } v_i \in M_i$$

$$\sum_{v_{-i} \in M_{-i}} \tilde{t}_i(\tilde{v}_i, v_{-i})\pi(v_{-i}|v_i) < 0 \qquad \text{for each } v_i \in M_i \text{ and } \tilde{v}_i \in M_i \backslash v_i$$

The constants $\tilde{t}_i$ described by Lemma 1 will be interpreted as transfer payments that depend on whether the reported value v_i is similar to the other reported values v_{-i}. In the displayed inequality, the "truth" is v_i (because v_i is the conditioning variable in the probability distribution), and firm i is assumed to have nontruthfully reported $\tilde{v}_i$. The constants $\tilde{t}_i$ can be scaled up to make the sum more negative. Thus the incentives to report truthfully can be made as strong as desired.

I now turn to procurement. I will start with an arbitrary procurement mechanism that is based on known valuations of the project, and then show that the decision rule implemented by the procurement mechanism can be implemented even when the firms' valuations must be elicited from them. Further, this can be done with no more dissipation of profit than when the valuations are known.

Most procurement problems (e.g., Sappington (1982), Laffont and Tirole (1986, 1987)) involve a moral hazard problem as well as a screening problem. However the arguments below are for a screening problem.

I define a *procurement mechanism* as (τ, d), where $\tau = \{\tau^i\}_{i \in N}$, and $d = \{d^i\}_{i \in N}$. The function $\tau^i : M \times K \to \mathbf{R}$ describes firm i's transfer, as it depends on the reported signals and costs, and $d^i : M \times K \to [0,1]$ is a decision function, as it depends on the reported signals and costs. The value $d^i(\tilde{v}, \tilde{c})$ is the probability that investment is procured from firm i. If the decision function is efficient, $d^i(\tilde{v}, \tilde{c}) = 0$ if firm i does not have the lowest cost. For a given procurement mechanism (τ, d) we define a profit function $\tilde{\Pi} = \{\tilde{\Pi}^i\}_{i \in N}$, $\tilde{\Pi}^i : M_i \times M_{-i} \times K_i \times K \to \mathbf{R}$, by

$$\tilde{\Pi}^i(\tilde{v}_i, v_{-i}, \tilde{c}_i, c) \equiv \tau^i(\tilde{v}_i, v_{-i}, \tilde{c}_i, c_{-i}) - d^i(\tilde{v}_i, v_{-i}, \tilde{c}_i, c_{-i})\, c_i$$

We say that the procurement mechanism has *bounded profits* if $\tilde{\Pi}$ is bounded, and we say that the procurement mechanism is *incentive compatible on cost* if for each $i \in N$, $v \in M$ and $c_i, \tilde{c}_i \in K_i$

$$\sum_{c_{-i} \in K_{-i}} \tilde{\Pi}^i(v_i, v_{-i}, \tilde{c}_i, c)\, f^{-i}(c_{-i}) \le \sum_{c_{-i} \in K_{-i}} \tilde{\Pi}^i(v_i, v_{-i}, c_i, c)\, f^{-i}(c_{-i}) \,. \qquad (1)$$

For a given procurement mechanism (τ, d), it is convenient to define the *expected profit function* $\Pi^i : M_i^2 \times K_i^2 \to \mathbf{R}$ by

$$\Pi^i(\tilde{v}_i, v_i, \tilde{c}_i, c_i) \equiv \sum_{v_{-i} \in M_{-i}} \sum_{c_{-i} \in K_{-i}} \tilde{\Pi}^i(\tilde{v}_i, v_{-i}, \tilde{c}_i, c)\ \pi^{-i}(v_{-i}|v_i)\ f^{-i}(c_{-i}) \,. \qquad (2)$$

The true value v_i enters the righthand side of (2) because the distribution of v_{-i} depends on the true value v_i and not on the reported value $\tilde{v}_i$.

We say that the procurement mechanism (τ, d) is *incentive compatible* if for each

$i \in N$ and $(v_i, c_i), (\tilde{v}_i, \tilde{c}_i) \in M_i \times K_i$,

$$\Pi^i(\tilde{v}_i, v_i, \tilde{c}_i, c_i) \leq \Pi^i(v_i, v_i, c_i, c_i). \tag{3}$$

We say that a procurement mechanism *achieves* profits $\hat{\Pi}^i : M_i \times K_i \to \mathbf{R}$ if $\hat{\Pi}^i(v_i, c_i) = \Pi^i(v_i, \hat{v}_i, c_i, c_i)$ for each $i \in N$ and $(v_i, c_i) \in M_i \times K_i$.

In the following proposition I restrict attention to procurement mechanisms with bounded profit functions. (The profit function would automatically be bounded if, for example, if each K_i, as well as M_i, were a finite set.)

The following proposition says that from a procurement mechanism that is incentive compatible on cost we can construct a procurement mechanism that is incentive compatible with respect to valuations as well, and that it implements the same decision rule and does not dissipate additional profit.

Proposition 1 *Consider a procurement mechanism (τ, d) that is incentive compatible on cost and has bounded profits. If Assumption 1 holds, there exists a function $t = \{t_i\}_{i \in N}$, $t_i : M \to \mathbf{R}$, such that the procurement mechanism $(\tau + t, d)$ is incentive compatible and achieves the same profits as (τ, d).*

Proof: Let B be the bound on profits $\tilde{\Pi}$, and suppose that the procurement mechanism (τ, d) achieves profits $\hat{\Pi}$. Let $t = k\tilde{t}$, where $\tilde{t}$ is the function described in Lemma 1, and let k be such that for all $i \in N$, $v_i \in M_i$ and $\tilde{v}_i \in M_i \backslash v_i$,

$$kE^{v_{-i}|v_i} t_i(v_i, v_{-i}) \equiv k \sum_{v_{-i} \in M_{-i}} \tilde{t}_i(\tilde{v}_i, v_{-i}) \pi(v_{-i}|v_i) < -2B$$

Provided the mechanism $(\tau + t, d)$ is incentive compatible, it achieves profits $\hat{\Pi}$, since $E^{v_{-i}|v_i} t_i(v_i, v_{-i}) = 0$ for all $i \in N$ and all (v_i, v_{-i}). It is incentive compatible because firm i loses at least $2B$ in expectation if it reports $\tilde{v}_i \neq v_i$, and $\Pi^i(\tilde{v}_i, v_i, \tilde{c}_i, c_i)$

$-\Pi^i(v_i, v_i, c_i, c_i) \leq 2B$. Thus, misrepresenting the signal of value and cost cannot increase profit. ■

Considering the inverse inclusion, it should be clear that under the assumptions on valuations and cost (valuations are correlated with each other, but not with costs, and costs are independent of each other), unobservability of valuations cannot reduce the amount of rent that must be dissipated in order to implement a given decision function d.

3 Squared-Deviation Mechanism

While the result in the previous section is quite general, it obscures how the correlation in signals is used. Payments depend on the signals of the other firms in a way that is very tied to the discreteness of the conditional distribution, and hard to describe intuitively.

An intuitive notion for how the correlation is used is that the firms are rewarded for reporting valuations that agree with each other, and punished for disagreeing. I now introduce a much simpler mechanism than the one above, which I call the the *squared deviation mechanism,* in which the punishments for disagreement are apparent. The only data about distributions used in this mechanism are the conditional means and variances of each signal (conditional on the other signals). However in order to guarantee full appropriation, taking account of individual rationality, the variance of the other firms' signals, conditional on v_i, must be the same for each v_i. This condition holds, for example, when the true underlying value of the project, say θ, is normally distributed, and for each $i \in N$, the signal v_i is generated as $v_i = \theta + u_i$ where u_i is normally distributed with mean zero and the same variance for each $i \in N$.

In the previous section, the signals of value were in abstract sets M_i. We shall now assume that the signals v_i are real values. The average of all signals other than v_i, $\bar{v}_{-i} \equiv \frac{\sum_{i \neq i} v_j}{|N|-1}$, is a random variable with distribution that depends on v_i. Let the distribution of $\bar{v}_{-i}$ be $\bar{\pi}_{-i}(\cdot|v_i)$, with mean represented by a function m_{-i}, that is, $m_{-i}(v_i) = \int \bar{v}_{-i}\ \bar{\pi}_{-i}(\bar{v}_{-i}|v_i)\ d\bar{v}_{-i}$. The assumption below that m_{-i} increases with v_i captures positive correlation among the firms' signals.

Assumption 2 *For each $i \in N$, the function m_{-i} is increasing, with derivative bounded away from zero, and for each v_i the distribution $\bar{\pi}_{-i}(\cdot|v_i)$ has variance $z > 0$.*

Define the *squared-deviation transfer function* $t^k = \{t_i^k\}_{i \in N}$, $t_i^k : M \to \mathbf{R}$, by

$$t_i^k(\tilde{v}_i, \bar{v}_{-i}) = k\ \left[\ z - (m_{-i}(\tilde{v}_i) -\ \bar{v}_{-i}\ )^2\right], \quad k > 0 \tag{4}$$

For each $i \in N$ and each $v_i, \tilde{v}_i \in M_i$, let

$$T_i^k(\tilde{v}_i, v_i) \equiv \int t_i^k(\tilde{v}_i, \bar{v}_{-i})\bar{\pi}(\bar{v}_{-i}|v_i)dv_{-i}.$$

Thus $T_i^k(\tilde{v}_i, v_i)$ is the expected transfer when firm i has true signal v_i and reports $\tilde{v}_i$.

Claim 1 [Incentive Compatibility and Individual Rationality] *Let t^k be the squared-deviation transfer function, with expected value T^k defined as above. Then for all $i \in N$ and for all $\tilde{v}_i, v_i \in M_i$, $T_i^k(\tilde{v}_i, v_i) \leq T_i^k(v_i, v_i)$. If Assumption 2 holds, then $T_i^k(\tilde{v}_i, v_i) < T_i^k(v_i, v_i) = 0$ for each v_i and $\tilde{v}_i \neq v_i$.*

Proof: Firm i reports the $\tilde{v}_i$ that solves

$$\max_{\tilde{v}_i}\ T_i^k(\tilde{v}_i, v_i) = \max_{\tilde{v}_i}\ k\ [\ z - \int\ (m_{-i}(\tilde{v}_i) - \bar{v}_{-i})^2\ \bar{\pi}_{-i}(\bar{v}_{-i}|v_i)\ d\bar{v}_{-i}\ ]$$

Firm i minimizes the expected squared error of the random variable $\bar{v}_{-i}$ around a value $m_{-i}(\tilde{v}_i)$, where $\bar{v}_{-i}$ is distributed according to $\bar{\pi}_{-i}(\cdot|v_i)$. That is, firm i would like to find the value m that minimizes $\int (m-\bar{v}_{-i})^2\, \bar{\pi}_{-i}(\bar{v}_{-i}|v_i)\, d\bar{v}_{-i}$. A solution is to set m equal to the mean of the distribution $\bar{\pi}_{-i}(\cdot|v_i)$, namely $m_{-i}(v_i)$. Any reported value $\tilde{v}_i \neq v_i$ gives a lower value of the maximand. The maximum is zero because the last term is equal to the variance z when v_i is reported truthfully. ■

We now apply this squared-deviation mechanism to procurement. As in Proposition 1, we will start with a procurement mechanism that is incentive compatible on cost, and add an additional transfer that makes it incentive compatible on both costs and reported values. As shown in the Claim, the squared-deviation transfer gives an incentive to report the valuation truthfully, and gives a nonzero punishment for lying about the valuation. However when appended to the procurement mechanism, there could still be an incentive to overstate the valuation in order to ensure that a profitable procurement mechanism is awarded (the decision function d^i would typically be increasing in v_i).

I show that for large k, the mechanism that appends the squared-deviation transfer to the procurement function is "almost" incentive compatible in the sense that each firm's profit is "almost" maximized when each firm reports the true signal. The optimal report will, in fact, be slightly higher than the true signal. I interpret "almost incentive compatible" to mean that if the possible types were discrete rather than continuous, then the mechanism with large k would be incentive compatible.

The constant k scales up the punishments for reporting a signal that disagrees with those of the other firms. The reason that large k ensures "almost" incentive compatibility, but not exact incentive compatibility, is that it is hard to punish the firm for infinitessimally over-reporting the signal. For an infinitessimal lie, the firm only increases the expected punishment by an infinitessimal amount.

For $\epsilon > 0$ we say that a procurement mechanism (τ, d) is $\epsilon -$ *incentive compatible* if (5) and (6) hold.

$$\| \arg\max_{\tilde{v}_i, \tilde{c}_i} \Pi^i(\tilde{v}_i, v_i, \tilde{c}_i, c_i) - (v_i, c_i) \| \quad < \epsilon \tag{5}$$

$$\max_{\tilde{v}_i, \tilde{c}_i} \Pi^i (\tilde{v}_i, v_i, \tilde{c}_i, c_i) - \Pi^i (v_i, v_i, c_i, c_i) < \epsilon \tag{6}$$

The first inequality means that the profit-maximizing reports are very close to the true signal and cost, and the second inequality means that the optimized profit is almost achieved by truthful reporting.

The following assumption is convenient for the proof.

Assumption 3 *The procurement mechanism (τ, d) has an expected profit function Π such that each Π^i is differentiable, nondecreasing in reported value $\tilde{v}_i$, and has partial derivatives that are bounded above.*

Proposition 2 *Suppose that a procurement mechanism (τ, d) is incentive compatible on cost and satisfies Assumption 3. Suppose Assumption 2 holds, and let t^k be the squared deviation transfer. Then for a fixed $b > 0$ the procurement mechanism $(\tau + t^k, d)$ is (b/k)-incentive compatible and achieves the same profits as (τ, d).*

Proof: Since (τ, d) is incentive compatible on cost, and since the additional transfer t^k does not depend on the reported cost, $(\tau + t^k, d)$ is also incentive compatible on cost. The optimizing $\tilde{c}_i$ is c_i, even if the optimizing $\tilde{v}_i$ is not exactly v.

First we show that (5) and (6) hold for $(\tau + t^k, d)$, that is, we need to show that

$$\| \arg\max_{\tilde{v}_i, \tilde{c}_i} [\Pi^i (\tilde{v}_i, v_i, \tilde{c}_i, c_i) + T_i^k(\tilde{v}_i, v_i)] - (v_i, c_i) \| < \epsilon \tag{7}$$

$$\max_{\tilde{v}_i, \tilde{c}_i} [\Pi^i (\tilde{v}_i, v_i, \tilde{c}_i, c_i) + T_i^k(\tilde{v}_i, v_i)] - [\Pi^i (v_i, v_i, c_i, c_i) + T_i^k(v_i, v_i)] < \epsilon \tag{8}$$

We shall write $\Pi_{\tilde{v}}^i$ for the derivative of Π^i with respect to the first argument $\tilde{v}_i$. Let $m'_{-i}(v_i) \geq \underline{m}'$ for all $i \in N$ and all $v_i \in M_i$, and let

$$b > \frac{\Pi_{\tilde{v}}^i(\tilde{v}_i, v_i, c_i, c_i)^2}{2\,[\underline{m}']^2}, \frac{\Pi_{\tilde{v}}^i(\tilde{v}_i, v_i, c_i, c_i)}{2\,[\underline{m}']^2} \qquad \text{for all } i \in N,\ \tilde{v}_i, v_i \in M_i,\ c_i \in K_i.$$

Let $(\tilde{v}_i, \tilde{c}_i) \equiv \arg\max_{\hat{v}_i, \hat{c}_i} [\Pi^i(\hat{v}_i, v_i, \hat{c}_i, c_i) + T_i^k(\hat{v}_i, v_i)]$. We have already observed that $\tilde{c}_i = c_i$. The maximizing $\tilde{v}_i$ satisfies

$$-2k\ m'_{-i}(\tilde{v}_i)\ \ (m_{-i}(\tilde{v}_i) - m_{-i}(v_i))\ +\ \Pi^i_{\tilde{v}}(\tilde{v}_i, v_i, c_i, c_i) = 0 \tag{9}$$

Then

$$|\tilde{v}_i - v_i|\ \underline{m'} \leq \int_{v_i}^{\tilde{v}_i} m_{-i}(v)dv = (m_{-i}(\tilde{v}_i) - m_{-i}(v_i))\ = \frac{\Pi^i_{\tilde{v}}(\tilde{v}_i, v_i, c_i, c_i)}{2k\ m'_{-i}(\tilde{v}_i)} < \frac{b\ \underline{m'}}{k} \tag{10}$$

Hence $|\tilde{v}_i - v_i| < \frac{b}{k}$, so (7) holds. The lefthand side of (8) is

$$T_i^k(\tilde{v}_i, v_i) - T_i^k(v_i, v_i) + \Pi^i(\tilde{v}_i, v_i, c_i, c_i) - \Pi^i(v_i, v_i, c_i, c_i) \leq \Pi^i(\tilde{v}_i, v_i, c_i, c_i) - \Pi^i(v_i, v_i, c_i, c_i)$$

$$\leq |\tilde{v}_i - v_i|\ \ \sup \Pi_{\tilde{v}}(\tilde{v}_i, v_i, c_i, c_i) \leq\ \ \frac{\Pi^i_{\tilde{v}}(\tilde{v}_i, v_i, c_i, c_i)^2}{2k\ m'_{-i}(\tilde{v}_i)\ \underline{m'}} < \frac{b}{k}$$

where the last line uses (10). Thus (8) holds as well. That the mechanism $(\tau + t^k, d)$ achieves the same profits as (τ, d) follows because $T_i^k(v_i, v_i) = 0$ for all $i \in N$, $v_i \in M_i$.
■

4 Interpretive Remarks

In order to ensure incentive compatibility, the payments might be very large and negative, which can lead to liquidity problems for the firm. In this sense the mechanism might be unrealistic. However it is important to stress that in expectation the transfers are small, and satisfy the individual rationality constraint. The assumptions that agents are risk neutral and that liquidity constraints do not bind seem more reasonable for firms than for individuals. Nevertheless, if firms were risk averse or liquidity constrained, the mechanism described here would not be optimal. With liquidity constraints the squared-deviation mechanism does not implement the optimum, and with risk aversion, extreme punishments are not optimal. However, although the mechanisms described here have these obvious shortcomings, the squared deviation mechanism also has the virtue of being very simple and easy to explain.

I have assumed that reservation payoffs are zero, reflecting the notion that if firms are not paid by the mechanism designer, there is no alternative payoff. This assumption might seem natural in the context of government procurement, where the government is the only demander, but even there it is suspect because the firm could invest without the procurement contract, and then try to peddle the product to the government ex post.

In the context of R&D, the assumption of zero reservation payoffs also means that there is no intellectual property protection, and that the invention will enter the public domain, whoever invents it, and however it is funded. I have made this assumption because my objective is to study procurement as an alternative to the patent system, rather than as a supplement to it. In contrast, Gandal and Scotchmer (1993), who study optimal mechanisms to coordinate research (in the sense of efficient delegation), and Scotchmer (1996), who studies incentives to license ex ante, assume that the reservation payoffs are determined by a patent race. The latter shows how a patentholder who wants to license his patent can exploit the interdependence of firms' strategies in the patent race so that both firms are held to payoffs that are smaller their "apparent" reservation payoffs (namely, the payoffs that would arise if both firms declined the contract and engaged in a race).

Such manipulations of the reservation payoffs could also be applied to the R&D context here. I have not included such complications because my main point is to show how the results on correlated information can be extended to procurement.

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