

Selecting an Agent's Ability

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Revised March 1991

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Financial Support from the National Science Foundation, the University of California Energy Research Group, and the Public Utilities Research Center at the University of Florida is gratefully acknowledged. We also wish to thank Lorne Carmichael, Curtis Eaton, Oliver Hart, William Rogerson, Thomas Ross, Pablo Spiller, Jean Tirole, Ralph Winter and seminar participants at U. C. Davis, Cal Tech, Carleton, Queens, Montreal, Toronto and Toulouse for helpful comments.

ABSTRACT

We examine the preferences of a principal (e.g., an employer) regarding the ability of the agent (e.g., an employee) in her employ. Higher levels of ability make higher productivity realizations more likely. The principal's preferences are shown to depend critically on the nature of the adverse selection problem she faces: high levels of ability are favored for agents with idiosyncratic skills, while low levels of ability are preferred for versatile agents with transferable skills.

1. Introduction.

An important task of employers is to assemble a reliable and economical work force. To succeed at this task, employers must carefully choose the type of individual to interview and ultimately to hire. Employers commonly deny employment to individuals whose skills are judged to be inadequate. On the other hand, employers will sometimes dismiss applicants who are "overqualified" for the job, even though they demand only the advertised compensation. Thus, some employers prefer more highly skilled employees (or agents) while other employers prefer agents of lesser ability. The primary purpose of this research is to examine the preferences of a principal (e.g., an employer) concerning the ability of the agent in her employ.

In our model, the agent's ability affects his likely productivity on the job. Furthermore, realized productivity is observed privately by the risk neutral agent, giving rise to an adverse selection problem. Consequently, increases in the agent's ability have two opposing effects. First, increased ability makes it more likely that the agent's realized productivity will be high. High productivity means that performance is less onerous for the agent, so total expected surplus is increased, *ceteris paribus*. Second, since the agent's equilibrium profit increases with realized productivity in these adverse selection problems, agents of higher ability may be more costly to the principal (e.g., the employer) in expectation. Given these two opposing effects, the risk neutral principal might prefer to contract with an agent of either greater or lesser ability.

It turns out that these *productivity* and *profit effects* are exactly offsetting in a wide class of problems. The additional expected profit the agent secures from enhanced ability is equal to the increase in expected total surplus that results from enhanced ability. This neutrality result holds in what we call the procurement setting, where there is a unique agent capable of producing for the principal. It also holds in what we refer to as the labor setting, where if one agent does not perform for the principal, another agent can be hired.

In the procurement setting, the *performance* effect determines the principal's preference

regarding the ability of the agent with whom she deals. The performance effect refers to the expected change in the level of the agent's performance (e.g., the amount of output he produces) as his ability increases. Higher ability increases the agent's expected level of performance in equilibrium. The increased performance turns out to be beneficial (detrimental) to the principal when the agent's performance is biased downward (upward) under the optimal incentive structure. Performance will be biased downward when the agent's skills are idiosyncratic to the task at hand. In this case, the agent's incentive to understate his productivity in the principal's employ is best mitigated by inducing performance levels that are inefficiently small. In contrast, performance will be biased upward when the agent is versatile, so that his skills in the principal's employ are also valuable elsewhere. In this case, the agent's incentive to exaggerate his opportunity wage is best mitigated by requiring the agent to undertake inefficiently high levels of performance. Therefore, the performance effect alleviates (compounds) the induced performance distortion in the case of an "idiosyncratic" ("versatile") agent, leading the principal to prefer an idiosyncratic agent of higher ability and a versatile agent of lower ability, *ceteris paribus*. In this sense, the nature of the *ex post* incentive problem facing the principal determines her preferences regarding her agent's ability in a procurement setting.

In a labor setting, an additional effect arises which enhances the performance effect. The *recontracting effect* comes into play when the agent who is initially selected may not produce for the principal, and so a new agent must be hired. There are two distinct costs associated with recontracting. First, the principal may incur agent-specific training costs each time a new agent is hired. Second, the production delays associated with hiring a new agent can be costly to the principal. To avoid both types of recontracting costs, the principal will wish to maximize the chances of inducing satisfactory performance from the agent who is first selected, *ceteris paribus*. In the case of an idiosyncratic agent, this goal is accomplished by securing the services of the agent with the highest ability. The greater the ability of the idiosyncratic agent, the less likely is his realized

productivity to be so low that the principal will choose to forego his services and hire a new agent. In contrast, to avoid recontracting costs the principal will choose from among those versatile agents capable of performing the task in question the agent of lowest ability. Lower levels of ability make lucrative alternative employment opportunities relatively less likely, thereby increasing the likelihood that the versatile agent first selected will remain in the principal's employ. Therefore, the recontracting effect, like the performance effect, causes the principal to prefer to contract with more (less) able idiosyncratic (versatile) agents.

The discussion to this point has taken the agent's ability to be observable and exogenous. In practice, the agent's ability will often be under his own control and difficult for the principal to measure accurately. For example, a contractor in a procurement setting may choose how much research and development to undertake in an attempt to discover a less costly means of production. Alternatively, an employee in a labor setting may choose how diligently to contemplate and study the task that he will be asked to perform. In settings like these, the principal can only influence her agent's ability indirectly through the incentive scheme she designs. We analyze this influence by comparing two situations: one where the agent selects his unobservable ability level before the principal can commit to an incentive structure, and the other where the timing is reversed.¹ We find that when the principal "moves first", she induces the idiosyncratic (versatile) agent to select a higher (lower) level of ability than he would select if he moved first. Furthermore, we demonstrate that the principal and agent may both prefer the principal to move first. Thus, both parties may favor a strengthening of the principal's commitment powers.

Our analysis proceeds as follows. The basic elements common to all of the models we analyze are described in section 2. In section 3, the procurement setting with observable ability is analyzed. The aforementioned neutrality result is proved, the performance effect is examined, and the principal's overall preference regarding the ability of agents is characterized. The labor setting

analyzed in section 4 permits a formal analysis of the recontracting effect. In section 5, we return to the procurement setting and examine how the basic preferences of the principal are manifested when she cannot directly observe the ability of agents, and when agents can control their ability levels. Conclusions are drawn in section 6. Formal proofs that are not central to the analysis are presented in the Appendix.

Before proceeding, we briefly review related work in the literature. The research most closely related to our own is Tirole's [1986] analysis of incentives for investment by a supplier in a procurement setting. Tirole examines a variety of bargaining structures, and allows for renegotiation and two-sided information asymmetry about the cost and value of a fixed level of output. His focus is on comparing the amount of investment the supplier will undertake to reduce production costs according to whether the investment is observable and verifiable, observable and unverifiable, or unobservable. Tirole restricts attention to settings where the procurer prefers suppliers of higher ability. In contrast, our focus (particularly in sections 2 through 4) is on identifying the key elements of the principal's preference regarding the exogenous and observable ability of the agent she hires to produce a variable level of output. We are particularly concerned with how this preference varies according to the *ex post* incentive problem she faces (i.e., whether the agent is idiosyncratic or versatile).

Baron and Besanko [1984] and Riordan [1988] also analyze procurement settings where *ex ante* investment affects *ex post* production costs. Baron and Besanko show how regulated prices are altered to enhance the incentives of a regulated firm to undertake cost-reducing research and development. Riordan shows how limiting the principal's ability to monitor the agent's *ex post* performance can encourage *ex ante* cost-reducing investment by the agent. (Also see Sappington [1986].)

2. Elements of the Models.

There are two risk-neutral actors in our model: the principal and the agent. The agent's observable performance level is denoted Q . For simplicity, suppose the agent's performance is the quantity of output he produces. The value to the principal of Q units of output is denoted $V(Q)$, where $V'(Q) > 0$ and $V''(Q) \leq 0 \quad \forall Q \geq 0$.

The agent's cost of producing output Q is $C(Q, c)$. The functional form of $C(\cdot)$ is common knowledge, but c is a cost parameter that is ultimately known privately to the agent. Unless otherwise specified, c can take on any value in a closed interval $[\underline{c}, \bar{c}]$.² Higher realizations of $c \in [\underline{c}, \bar{c}]$ imply higher total and marginal costs of production for the agent, i.e., $C_2(\cdot) > 0$ and $C_{12}(\cdot) > 0$, where subscripts denote the obvious partial derivatives. For all values of c , marginal costs of production are nondecreasing in output, i.e., $C_1(\cdot) > 0$ and $C_{11}(\cdot) \geq 0$. The cost parameter, c , is modeled as the realization of a random variable with distribution $F(c|\cdot)$ and corresponding density $f(c|\cdot)$. Following much of the incentive literature, we assume

$$\frac{d}{dc} \left\{ \frac{F(c|\cdot)}{f(c|\cdot)} \right\} \geq 0 \quad \text{and} \quad \frac{d}{dc} \left\{ \frac{1 - F(c|\cdot)}{f(c|\cdot)} \right\} \leq 0 \quad \forall c \in [\underline{c}, \bar{c}].$$

Of central concern in our analysis is the effect of the agent's ability, e , on his productive capabilities. One can think of ability as education, training, or personal diligence that improves the agent's likely productivity. Formally, we condition the agent's distribution of production costs on e , and presume that higher values of e reduce production costs in the sense of first-order stochastic dominance, i.e., $F_e(c|e) \geq 0 \quad \forall c$, with strict inequality for some $c \in (\underline{c}, \bar{c})$. Diminishing returns to ability are assumed, i.e., $F_{ee}(c|e) \leq 0 \quad \forall c, e$. It is further assumed that

$$\frac{d}{de} \left\{ \frac{f(c|e)}{F(c|e)} \right\} \leq 0 \quad \text{and} \quad \frac{d}{de} \left\{ \frac{f(c|e)}{1 - F(c|e)} \right\} \geq 0 \quad \forall c \in (\underline{c}, \bar{c}).^3$$

These regularity conditions require the conditional probability of the largest c realization in any

interval $[\underline{c}, c]$ to decrease, and the conditional probability of the smallest c realization in any interval $[c, \bar{c}]$ to increase with the agent's ability.

In addition to affecting his cost of producing for the principal, the realization of c may also influence the agent's cost of producing elsewhere, and thus his opportunity wage. We denote by $\bar{\pi}(c)$ the agent's maximal expected profit in alternative employment when c is the realized value of his cost parameter. A critical element of our analysis is whether, in equilibrium, the agent earns exactly his reservation wage for the smallest or for the largest realizations of c . The agent earns no rents for the highest c realizations when his alternative earnings are not affected by the level of his (idiosyncratic) skill in the principal's employ (i.e., $\bar{\pi}(c) = 0 \quad \forall c \in [\underline{c}, \bar{c}]$). This is the standard case in the adverse selection literature, where the agent's *ex post* incentive is always to exaggerate realized production costs. We will refer to this case as the case of the *idiosyncratic agent*.

The agent may have reason to understate the realization of c when lower production costs in the principal's employ correspond to lower costs and thus greater expected earnings in alternative sectors (i.e., when $\bar{\pi}(c) < 0 \quad \forall c \in [\underline{c}, \bar{c}]$).⁴ By understating c , the agent exaggerates his opportunity wage, thereby claiming to require greater compensation in order to work for the principal. When the agent's opportunity wage rises sufficiently rapidly as c falls (i.e., when $|\bar{\pi}(c)|$ is sufficiently large), the agent's *ex post* incentive will always be to understate the realization of c . Furthermore, the agent will be held to his reservation wage only for the smallest realizations of c . We will refer to this case as the case of the *versatile agent*.⁵

Before proceeding, it is important to emphasize that the principal's preference for reduced ability on the part of a versatile agent does not arise because the agent's *full* costs of production (i.e., variable costs plus opportunity costs) may decline with c . To the contrary, settings are readily derived where, when the realization of c publicly observed, total surplus from production is maximized at some small value of $c \in [\underline{c}, \bar{c}]$, and yet when the versatile agent observes the realization of c

privately, the principal will prefer an agent of lesser ability. (See Propositions 1 and 2 below.) This fact is explained in more detail in Section 3.

It should also be explained why we have taken the agent's reservation wage to depend only on his realized productivity, and not on his initial level of ability. This restriction is natural when the agent's skills are idiosyncratic or when his ability level is unobservable (as in the analysis of section 5). However, one might expect the reservation wage of a versatile agent to increase when his observable ability level increases. In this case, though, versatile agents of higher ability are more expensive for the principal to hire. We abstract from this bias against versatile agents of high ability, focusing instead on less obvious reasons a principal will prefer versatile agents of lower ability.

3. Observable Ability in the Procurement Setting.

In this section, we take the ability level of each agent to be observable and exogenous. We consider a procurement setting where the costs of recontracting are prohibitive, so if the agent who is initially chosen by the principal refuses to produce or is dismissed, the principal does not subsequently contract with another agent.

To examine the principal's preference regarding the ability of the selected agent, it is useful to first examine the principal's optimal strategy for any given level of ability, e . The principal's task in this setting is to design a compensation structure that maximizes her expected net welfare while guaranteeing the agent at least his reservation wage for all realizations of c .⁶ Letting $Q(c)$ denote the agent's equilibrium performance when c is realized, and $T(c)$ the corresponding transfer payment from the principal to the agent, the principal's problem [P] is:

$$\text{Maximize}_{Q(c), T(c)} \int_{\underline{c}}^{\bar{c}} [V(Q(c)) - T(c)] dF(c|e) \quad (3.1)$$

subject to, $\forall c, \hat{c} \in [\underline{c}, \bar{c}]$:

$$\pi(c) \geq \bar{\pi}(c), \text{ and} \quad (3.2)$$

$$\pi(c) \geq \pi(\hat{c}|c), \quad (3.3)$$

where $\pi(\hat{c}|c) \equiv T(\hat{c}) - C(Q(\hat{c}), c)$ and $\pi(c) \equiv \pi(c|c)$.

The individual rationality constraints (3.2) ensure the agent's most lucrative employment is with the principal. The incentive compatibility constraints (3.3) define $Q(c)$ and $T(c)$, ensuring that the agent will truthfully "report" his private information to the principal.

Using standard techniques (e.g., Baron and Myerson [1982], Laffont and Tirole [1986], and Lewis and Sappington [1989a]), the following properties of the interior solution to [P] are readily derived.⁷

Lemma 1. $Q'(c) \geq 0$ a.e., and $\pi'(c) = -C_2(Q, c) \leq 0 \quad \forall c \in [\underline{c}, \bar{c}]$ in the solution to [P].

Lemma 2. In the case of the idiosyncratic agent, the solution to [P] has $Q(c) \leq Q^*(c) \equiv \underset{Q}{\operatorname{argmax}} \{V(Q) - C(Q, c)\} \quad \forall c \in [\underline{c}, \bar{c}]$, with strict inequality for $c > \underline{c}$.

Lemma 3. In the case of the versatile agent, the solution to [P] has $Q(c) \geq Q^*(c) \quad \forall c \in [\underline{c}, \bar{c}]$, with strict inequality for $c < \bar{c}$.

Lemma 2 is a standard result in models of adverse selection: the agent is induced to produce less than the efficient output ($Q^*(c)$) in order to limit his incentive to exaggerate realized production costs. The smaller output levels associated with the higher realizations of c reduce the differential

in total production costs for any two distinct values of c , thereby limiting the potential gain to the agent from exaggerating realized costs.

Lemma 3 demonstrates a key difference that arises in the case of the versatile agent. To limit the agent's incentive to understate c (and thereby exaggerate his reservation wage), inefficiently large output levels are induced when the smaller realizations of c are reported. The extra output is more costly for the agent to produce the higher the actual realization of c , thereby limiting the attraction to the agent of understating c .

Lemmas 1 - 3 are instrumental in proving Proposition 1, the main conclusion of this section. The Proposition describes the principal's preferences regarding the agent's ability. These preferences are captured by $V^*(e)$, which is defined to be the value of the principal's objective function (3.1) in the solution to [P] when the agent's ability is e .

Proposition 1. $V^{*'}(e) > 0 \quad \forall e \geq 0$ in the case of the idiosyncratic agent. $V^{*'}(e) < 0 \quad \forall e \geq 0$ in the case of the versatile agent.

Proof. Using standard techniques (e.g., Baron and Myerson [1982] and Laffont and Tirole [1986]), the principal's objective function in the case of the idiosyncratic agent can be rewritten as:⁸

$$V^*(e) = \int_{\underline{c}}^{\bar{c}} \left\{ V(Q(c)) - C(Q(c), c) - \frac{F(c|e)}{f(c|e)} C_2(Q(c), c) \right\} f(c|e) dc.$$

Therefore, via the envelope theorem,

$$V^{*'}(e) = \int_{\underline{c}}^{\bar{c}} \left\{ [V(Q(c)) - C(Q(c), c)] f_c(c|e) - F_c(c|e) C_2(Q(c), c) \right\} dc. \quad (3.4)$$

Integration by parts of the first term in (3.4) provides

$$V^{**}(e) = - \int_{\underline{c}}^{\bar{c}} [V'(Q(\cdot)) - C_1(Q(\cdot), c)] Q'(c) F_c(c|e) dc \quad (3.5)$$

> 0 by Lemmas 1 and 2.

Similarly, following Lewis and Sappington [1989a], the principal's objective function in the case of the versatile agent can be rewritten as

$$V^*(e) = \int_{\underline{c}}^{\bar{c}} \left\{ V(Q(c)) - C(Q(c), c) - \bar{\pi}(c) + \frac{1 - F(c|e)}{f(c|e)} C_2(Q(c), c) \right\} f(c|e) dc. \quad (3.6)$$

Differentiation of (3.6) and integration by parts provides exactly the expression recorded in (3.5).

This expression is negative in the case of the versatile agent, by Lemmas 1 and 3. ■

There are three distinct effects that underlie the conclusions of Proposition 1. The *productivity effect* leads the principal to favor higher levels of ability. Higher values of e make smaller c realizations more likely, thereby enhancing the agent's expected productivity. The corresponding reduction in expected costs of producing any specified level of output increases total expected surplus, raising the principal's expected net welfare, *ceteris paribus*.

A countervailing effect is the *profit effect*. Higher ability levels and the associated smaller expected realizations of c imply greater expected equilibrium profits for the agent. (Recall $\pi'(c) \leq 0$ from Lemma 1.) It turns out that the productivity and profit effects are exactly offsetting. In other words, the agent is, in expectation, able to secure in the form of profit any increase in expected total surplus that arises from smaller expected production costs. To document this neutrality result formally, define the total expected surplus as

$$S(e) \equiv \int_{\underline{c}}^{\bar{c}} [V(Q(c)) - C(Q(c), c)] dF(c|e). \quad (3.7)$$

Differentiation of (3.7) and integration by parts reveals

$$S'(e) = \int_{\underline{c}}^{\bar{c}} \left\{ C_2(Q(c), c) [-F_c(c|e)] + [V'(Q(c)) - C_1(Q(c), c)] Q'(c) [-F_c(c|e)] \right\} dc. \quad (3.8)$$

From Lemma 1, the first term in (3.8) (the productivity effect) is precisely the rate at which the agent's equilibrium expected rents rise with e (the profit effect).

Given this neutrality result, the pivotal effect is a third one that we call the *performance effect*. Formally, this effect is captured by the second term in (3.8), which is precisely the effect identified in (3.5). The performance effect arises because higher ability makes the smaller c realizations and thus the larger output levels more likely. (Recall $Q'(c) \leq 0$ from Lemma 1.) The larger output levels are associated with the smaller production distortions ($Q(c) < Q^*(c)$) in the case of the idiosyncratic agent. The most severe distortions are implemented for the large c realizations to limit the agent's incentive to exaggerate realized production costs. Therefore, since increased ability reduces the chances of incurring the most severe performance distortions, the performance effect leads the principal to favor greater ability for the idiosyncratic agent.⁹ In contrast, the smaller c realizations and larger output levels are associated with the greatest production distortions ($Q(c) > Q^*(c)$) in the case of the versatile agent. The most severe distortions are implemented for the small c realizations to limit the incentives of the versatile agent to exaggerate his reservation wage. Consequently, since these large distortions are more likely to be incurred the greater the agent's ability, the performance effect leads the principal to prefer reduced ability on the part of the versatile agent.

As noted above, the principal's desire to reduce the ability of the versatile agent is not an

artifact of the possibility that the agent's full costs of production may decline with c when $\bar{\pi}'(c) < 0$. To see this, define gross surplus as $S^*(c) \equiv V(Q^*(c)) - C(Q^*(c), c)$, and net surplus as $S^*(c) - \bar{\pi}(c)$. Net surplus varies with c at the rate $-C_2(Q^*(c), c) - \bar{\pi}(c)$. Therefore, in the setting depicted in Figure 1, net surplus is highest when the relatively small cost realization, \tilde{c}^* , occurs. Consequently, in a first-best world with no adverse selection concerns, the principal would generally not choose the smallest level of ability for the agent. However, in second-best settings corresponding to Figure 1, where the individual rationality constraint binds for the versatile agent at \underline{c} , the principal will always prefer the smallest level of ability for the versatile agent.¹⁰

4. Observable Ability in the Labor Setting.

The discussion to this point has focused on a procurement setting where it was prohibitively costly for the principal to recontract with a second agent. In many settings, though, the services of one agent (e.g., a relatively unskilled worker) are readily substituted for those of another, and the costs of retraining and delay are small relative to the principal's expected gains from contracting with a new agent. The purpose of this section is to examine any additional elements of the principal's calculus that arise in such labor settings.¹¹

To illustrate the key new element most simply, suppose all agents have the same observable level of ability, e . Also suppose the principal deals with at most one agent in any time period. Further suppose that each time the principal deals with a new agent, she incurs a nonnegative training or renegotiation cost of t dollars. After he is trained by the principal, the agent learns privately exactly what his productivity (c) will be if he works for the principal. The principal then offers a contract to the agent. Next, the agent either selects the most profitable $\{Q(c), T(c)\}$ option from the contract offered by the principal or terminates his relationship with the principal. Termination will occur if the most profitable option under the contract promises the agent less

than his reservation wage, $\bar{\pi}(c)$. If termination occurs, the principal chooses another agent, and the process begins anew. If the agent can earn more profit working for the principal than working elsewhere, he delivers the chosen output level to the principal in return for the promised compensation. The interaction between principal and agent ends at this point.

When the possibility of recontracting arises in labor settings, the productivity, profit, and performance effects all influence the principal's calculus as described above. In addition, a *recontracting effect* operates in the same direction. The principal wishes to avoid retraining costs and losses from delay in obtaining output that arise when a selected agent ultimately does not produce for the principal. Consequently, the principal has reason to select agents who are more likely to produce for her after learning their production costs. In labor settings, the principal will induce strictly positive output from the idiosyncratic agent who turns out to have sufficiently small production costs ($c \in [c, c^I]$). She will terminate the employment of the selected idiosyncratic agent and hire a new one when the selected agent's realized costs are too high ($c \in (c^I, \bar{c}]$). In contrast, the principal will retain the services of the selected versatile agent who reports to have a low reservation wage ($c \in [c^V, \bar{c}]$), while the versatile agent with more attractive alternative opportunities ($c \in [c, c^V]$) will choose not to produce for the principal. Consequently, the recontracting effect will lead the principal to prefer idiosyncratic agents whose expected production costs are low (i.e., those of high ability), and to prefer versatile agents with low expected opportunity wages (i.e., those of low ability).

A formal characterization of the recontracting effect is provided in Proposition 2. In the statement of the Proposition, $V^I(e)$ represents the principal's maximum expected utility (gross of training costs, t) in the labor setting when all agents are idiosyncratic and each is known to have ability e . $V^V(e)$ is the corresponding measure of expected utility for the principal who deals with versatile agents of ability e .

Proposition 2. For all $e \geq 0$,

$$\begin{aligned}
 V^I(e) - & - \int_{\underline{c}}^{c^I} [V'(Q(c)) - C_1(Q(c), c)] Q'(c) F_c(c|e) dc \\
 & + \left\{ [V(Q(c^I)) - C(Q(c^I), c^I)] - \beta[V^I(e) - t] \right\} > 0; \text{ and} \quad (4.1)
 \end{aligned}$$

$$\begin{aligned}
 V^V(e) - & - \int_{c^V}^{\bar{c}} [V'(Q(c)) - C_1(Q(c), c)] Q'(c) F_c(c|e) dc \\
 & + \left\{ [V(Q(c^V)) - C(Q(c^V), c^V) \bar{\pi}(c^V)] - \beta[V^V(e) - t] \right\} < 0. \quad (4.2)
 \end{aligned}$$

The first line in each of equations (4.1) and (4.2) corresponds exactly to equation (3.5), which reflects the combined influence of the productivity, profit, and performance effects in the procurement setting. The second line in (4.1) and in (4.2) reflects the additional impact of an increase in the agent's ability when recontracting is possible. When the agents are idiosyncratic, an increase in e reduces the probability that the realized cost of the selected agent will be so large that the principal will dismiss the agent and hire a new one. As shown in the Appendix, the cutoff cost realization, c^I , is optimally chosen so that the principal's net gain from dealing with the marginal agent ($V(Q(c^I)) - C(Q(c^I), c^I)$) exceeds the principal's expected gain from recontracting ($\beta[V^V(e) - t]$). The marginal agent with cost realization c^I is dismissed even though his net contribution to the principal is positive in order to limit the rents that accrue to the producing agent when lower values of c are realized. Therefore, the second line in (4.1), like the first, is positive, providing an additional reason the principal prefers idiosyncratic agents of higher ability. The optimal cutoff cost realization, c^V , for the versatile agent is also selected so that the principal prefers to retain the marginal agent rather than recontract with a new agent. This

ensures the second line in (4.2), like the first, is negative. Consequently, the recontracting effect leads the principal to prefer versatile agents of lower ability.

For simplicity, the discussion of the labor setting to this point has taken the ability levels of all agents to be identical and observable. The analysis is readily extended to settings where the abilities of agents differ, and the principal only learns the ability of a particular agent by interviewing that agent.¹² After the agent's ability is discerned, the principal must decide whether to train that agent (thereby providing the agent with private knowledge of c) or to select a new agent to interview from the population of agents who appear identical *ex ante*. The principal's optimal strategy in this setting is readily derived. When the agents are idiosyncratic, the principal will train the agent who has been interviewed if his ability is found to be sufficiently high. An agent of lower ability will be deemed to have failed the interview and will not be trained, because his expected production costs and the anticipated probability of having to ultimately interview and train a new agent are too high. In contrast, the versatile agent who is found to have sufficiently low ability will be trained. The versatile agent with higher ability will not be trained, since the principal believes the chances of ultimately retaining the services of this agent are too small. A new versatile agent will be interviewed instead.

5. Endogenous, Unobservable Ability.

In this section, we abstract from the recontracting effect and return to the procurement setting to consider the effects of unobservable and endogenous ability levels. More precisely, we assume the agent can, at personal cost, select his most preferred level of ability. For example, an expert may decide how intensively to "study" the particular problem at hand, thereby improving his expected productivity on the job. Alternatively, a contractor may choose how much research and development to undertake before beginning production of the item that is being procured. To capture most simply the idea that ability is difficult to measure, we assume the agent's ability

is unobservable to the principal.¹³ Two scenarios are considered. In one setting, the principal "moves first" by committing to a final compensation structure before the agent selects his level of ability. This timing may be relevant, for example, when a firm establishes a long-lived pay schedule before a potential employee decides how extensively to develop his skills. In the second setting, the agent moves first by choosing his ability before (or, equivalently, at the same time as) the principal commits to a compensation structure. For example, a supplier may develop expertise before a buyer proposes a procurement contract.

In the setting where the principal moves first, the complete timing of the interaction between principal and agent is the following. First, the principal announces the incentive scheme $\{T(\cdot), Q(\cdot)\}$ that specifies transfer payments to the agent according to his observed performance level. Second, the agent chooses an ability level, e . The personal cost to the agent of each unit of ability is normalized to unity. Third, the agent privately observes the realization of his production cost, c . He then decides how much output to produce. Finally, the principal compensates the agent for the delivered output, as promised. The complete timing in the setting where the agent moves first differs only in that the chronology of the first two events is reversed: the agent chooses e before (or, equivalently, at the same time as) the principal chooses a payment structure.

For expositional ease, a formal statement of these two problems is relegated to the Appendix. The key feature of their solutions is recorded in Proposition 3. The Proposition makes reference to e^i , which is defined to be the level of ability selected by the agent when party i ($= P$ for principal or A for agent) moves first.

Proposition 3. $e^P > e^A$ in the case of the idiosyncratic agent. $e^P < e^A$ in the case of the versatile agent.¹⁴

When the agent moves first, he chooses his most preferred ability level knowing the principal will design an incentive scheme to maximize her expected welfare, taking as given the agent's ability.¹⁵ In the case of the idiosyncratic agent, the principal induces less than the efficient output level from the agent. (Recall Lemma 2.) The reduced output limits the rents the agent commands from his private knowledge of c by making these rents increase as c declines less rapidly than they would if efficient production decisions were implemented. Correctly anticipating an incentive scheme of this form, the agent perceives diminished returns to increasing the likelihood of low c realizations by improving his ability. Consequently, he chooses to acquire less than the efficient ability level, $e^A < e^* \equiv$

$$\operatorname{argmax}_e \left\{ \int_{\underline{c}}^{\bar{c}} [V(Q^*(c)) - C(Q^*(c), c)] dF(c|e) - e \right\} .$$

When the principal moves first, she can mitigate this distortion to some extent by committing to an incentive scheme in which the profits of the idiosyncratic agent are more sensitive to the realization of c . This enhanced sensitivity is created by increasing the agent's equilibrium output level for some realizations of $c \in (\underline{c}, \bar{c}]$. Although the increased output can increase the agent's expected rents, the increased output and the concomitant increase in the agent's ability leads to a higher level of total expected surplus. Because she is able to capture some of this increased surplus for herself, the principal will induce a higher level of ability from the idiosyncratic agent when she moves first.

The logic in the case of the versatile agent is similar. When the agent moves first, the principal reacts to the agent's chosen ability level by inducing output in excess of the efficient level. (Recall Lemma 3.) This expanded output increases the sensitivity of the agent's

equilibrium profits to the realization of c , thereby providing expanded incentive to increase ability, leading the agent to select $e^A > e^*$. When the principal moves first, she induces less output from the agent for some realizations of $c \in [c, \bar{c})$. The reduced output can increase the agent's expected rents. However, it also induces the agent to select a smaller level of ability, because the reduced output diminishes the sensitivity of the agent's profit to the realization of c , thereby reducing the expected returns from enhanced ability. The induced reduction in ability and the reduced output both increase the total expected surplus, some of which is captured by the principal.

The fact that the agent's profit may increase (due to either increased rents or diminished effort) when the principal moves first introduces the possibility that both the principal and agent may prefer to have the principal move first.¹⁶ This possibility is illustrated in Proposition 4, where we consider the *binary setting*. In this setting, $c \in \{c_1, c_2\}$ with $c_1 < c_2$, and $p(e)$ is the probability that c_1 is realized when the agent's ability level is e . Increases in ability increase (at a decreasing rate) the probability of the low cost realization, i.e, $p'(e) > 0$ and $p''(e) < 0 \forall e \geq 0$, where $p'(0) = \infty$ and $p'(\infty) = 0$.

Proposition 4. Suppose $|C_{112}(\cdot)|$ is sufficiently small. Then in the binary setting, the equilibrium expected welfare of both the principal and the agent is strictly higher when the principal moves first than when the agent moves first.

When the critical cost parameter is binary, it is possible to rank output levels across regimes for every realization of c . This ranking, in turn, ensures the joint preference recorded in Proposition 4 for having the principal move first. In the case of the idiosyncratic agent, the principal induces a higher ability level when she moves first by requiring more output from the agent when c_2 is realized, and the same (efficient) output when c_1 is realized. The expanded

output when c_2 occurs results in more rents for the agent when c_1 is realized, thereby increasing his expected profits. In the case of the versatile agent, the principal induces a smaller ability level when she moves first by inducing less output when c_1 is realized and the same (efficient) output when c_2 is realized. The smaller output under c_1 provides expanded rents for the agent when c_2 occurs, thereby increasing his expected profits. Of course, in both cases the principal prefers to move first, because she can always commit to offer the same incentive scheme she would offer if the agent had already selected his ability level.

Outside of the binary environment, such a systematic ranking of output levels (and, consequently, profit levels) is more problematic. Nevertheless, it is interesting to note that settings exist where the two parties both prefer to have the principal move first. In this sense, both principal and agent may prefer to enhance the principal's power of commitment.

6. Conclusions and Extensions.

We have examined a variety of simple models to analyze a principal's preference regarding the ability of an agent with whom she contracts in the presence of adverse selection. A strong neutrality result was derived: the extra profit the agent anticipates from enhanced ability exactly offsets the extra surplus expected to flow from the greater productivity, *ceteris paribus*. Thus, the principal's overall preference is determined by the effect of enhanced ability on recontracting costs and the incidence of performance distortions under the optimal incentive contract. These effects lead the principal to choose idiosyncratic agents with high ability and versatile agents with low ability when their ability levels are observable. When ability is unobservable and under the agent's control, the principal who moves first will induce a higher (lower) level of ability from the idiosyncratic (versatile) agent than the agent chooses when he moves first.

To simplify the exposition, our analysis of the models with endogenous ability assumed the

level of ability chosen by the agent was not observable to the principal. In practice, though, some measure of an agent's ability (e.g., his level of education) will often be observable. When the agent's ability level is publicly observable, results emerge which are the natural extensions of the findings derived in section 5. In particular, when the principal moves first, she will instruct the idiosyncratic agent to select an even higher ability level (e_o^P) than she induces from him when his ability level is unobservable. When the idiosyncratic agent moves first, he chooses a smaller ability level (e_o^A) when ability is publicly observable than when it is not. The observable commitment to reduced ability leads the principal to expect the larger values of c to be realized with greater frequency. As a result, the principal reduces the production distortions associated with the higher realizations of c . The increased output levels lead to greater rents for the idiosyncratic agent (recall Lemma 1), which explains his preference for reduced ability.¹⁷

For similar reasons, the versatile agent who moves first will select an observable ability level in excess of the level he chooses when his ability is not publicly observable. The increased ability leads the principal to anticipate the smaller c realizations, so she reduces induced quantity levels toward their efficient levels for these small c realizations. The result is increased expected rents for the versatile agent. In contrast, when the agent's ability is observable and the principal moves first, she will instruct the versatile agent to choose a smaller ability level than she induces when ability is not observable. Intuitively, it is less costly for the principal to pursue her preference for reduced ability on the part of the versatile agent when his ability is observable.

These observations are summarized in Proposition 5. In the statement of the Proposition, e^A and e^P are as defined above, while e_o^A (e_o^P) is the agent's equilibrium ability level when the agent (the principal) moves first and the agent's ability level is observable.¹⁸

Proposition 5. $e_o^P > e^P > e^A > e_o^A$ in the case of the idiosyncratic agent. $e_o^A > e^A > e^P > e_o^P$ in the case of the versatile agent.

The exposition in this paper was also facilitated by focusing on just two types of *ex post* adverse selection problems: the case of the idiosyncratic agent and the versatile agent. More generally, the binding *ex post* problem for the principal may be to prevent the agent from exaggerating some realizations of his private information and understating other realizations. (See Lewis and Sappington [1989a,b].) In such settings, the principal's preferences regarding the agent's ability may be more complex. Our conjecture is that the principal will prefer agents of particularly high or particularly low ability to those of intermediate ability.

In closing, we note that our findings seem to have relevance beyond the strict confines of our model. To illustrate, consider the setting where agents with private information about their ability bid for the right to serve a principal (as in Laffont and Tirole [1987b], McAfee and McMillan [1987], and Riordan and Sappington [1987]). Because of the effects identified here, the principal may not always design the auction so that the winning agent is the one with the highest ability. This possibility has interesting implications for procurement policy.

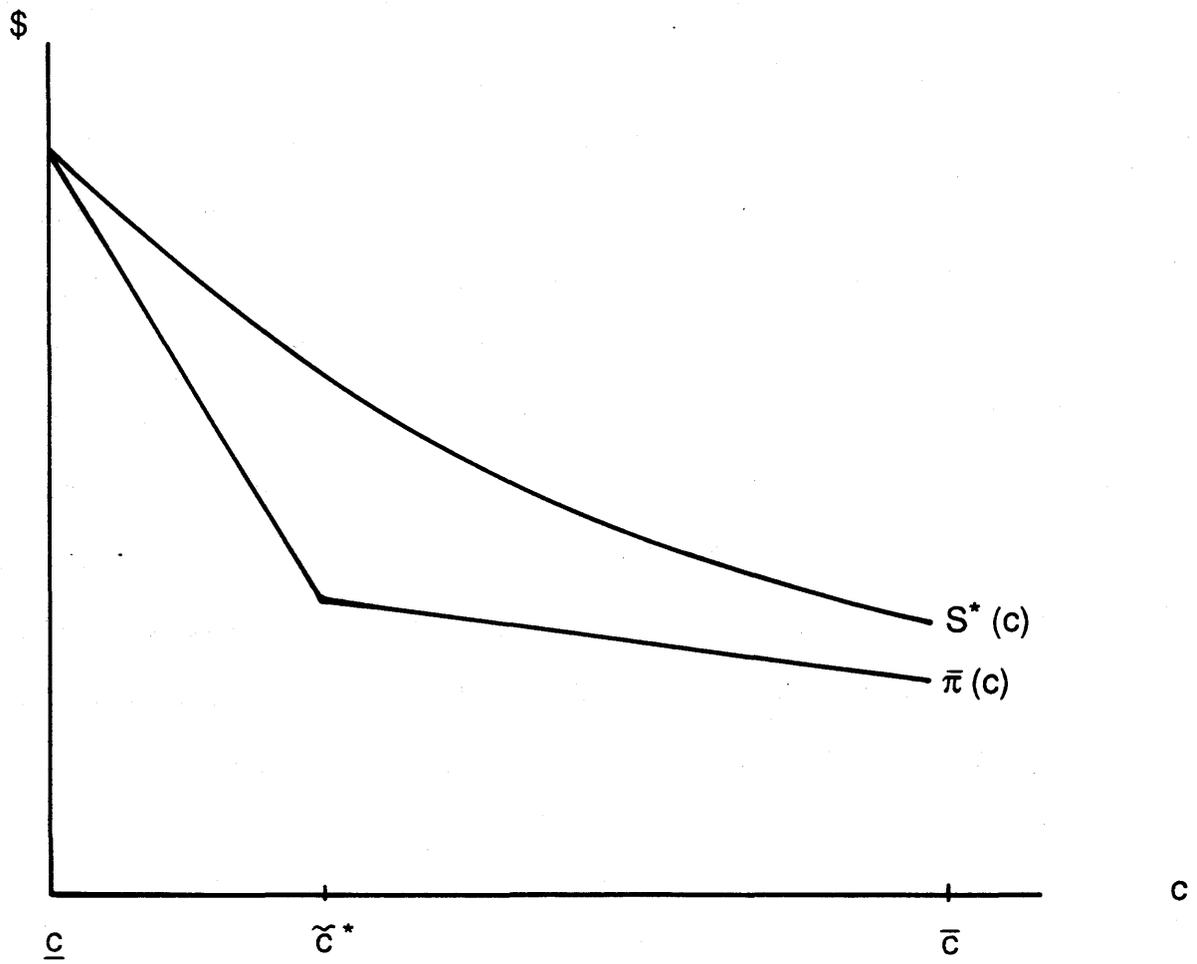


Figure 1. First - Best Preferred c Realization, \tilde{c}^* .

FOOTNOTES

1. In the concluding section, we also provide some results for these two cases when the agent's ability (e.g., his level of schooling) is publicly observable.
2. In Proposition 4, we consider the possibility that the distribution of c is discrete.
3. Tirole [1986] also introduces the first of these assumptions in his analysis. The assumption is implied by the monotone likelihood ratio property. (See Milgrom (1981).)
4. Employers in other sectors need not be able to observe the realization of c in order to ensure $\bar{\pi}'(c) < 0 \quad \forall c \in [\underline{c}, \bar{c}]$. Optimal incentive schemes in the presence of asymmetric information can provide greater payoffs to the agent with lower production costs.
5. Formally, a(n endogenous) condition sufficient to ensure that we are in the case of the understating agent is $|\bar{\pi}'(c)| \geq C_2(Q(c), c) \quad \forall c \in [\underline{c}, \bar{c}]$, where $Q(c)$ is the equilibrium performance level of the agent. (Corresponding exogenous conditions which simply require $|\bar{\pi}'(c)|$ to be sufficiently large are readily derived. See Lewis and Sappington [1989a] and Champsaur and Rochet [1989].) This sufficient condition is, in general, not a necessary condition.
6. Thus, we adopt the standard assumption that the agent is always free to leave the principal's employ after learning his productivity. Furthermore, we assume the agent cannot post a bond with the principal before learning his productivity, perhaps because of wealth constraints.
7. For simplicity, we assume that in all procurement settings, the agent's performance is sufficiently valuable to the principal that $Q(c) > 0 \quad \forall c \in [\underline{c}, \bar{c}]$ in equilibrium. Our

qualitative results are not sensitive to this assumption. The possibility that an agent might produce no output is considered in the labor setting of section 4.

8. Throughout, we impose only the local incentive compatibility constraints. It is straightforward to verify that the corresponding global constraints in [P] will be satisfied if $C_{112}(\cdot)$ and $C_{122}(\cdot)$ are sufficiently small in absolute value.
9. In the exercise conducted here, there is no direct cost associated with improving the agent's ability. When this cost is introduced, diminishing returns will ensure that the principal's demand for the ability of an idiosyncratic agent is not unbounded .
10. The following setting is consistent with the main elements of Figure 1:

$$V(Q) = 37Q - Q^2, \quad C(Q, c) = cQ,$$

$$\bar{\pi}(c) = \begin{cases} 250 - 50c & \forall c \in [1, 2.5] \\ 165 - 16c & \forall c \in [2.5, 5] \end{cases}, \quad \text{and} \quad f(c) = \begin{cases} \frac{1}{4} & \forall c \in [1, 5] \\ 0 & \forall c \in [1, 5] \end{cases}.$$

It is straightforward to verify that since $Q^*(c) = \frac{37-c}{2}$, $|S''(c)| < |\bar{\pi}'(c)| \quad \forall c \in [1, 2.5]$ while $|\bar{\pi}'(c)| > |S''(c)| \quad \forall c \in (2.5, 5]$. Therefore $\tilde{c}^* = 2.5$. It is also readily shown that the individual rationality constraint (3.2) binds at \underline{c} in this setting, so the principal prefers the versatile agent of lowest ability.

11. We thank Lorne Carmichael for suggesting this extension of our analysis.
12. Details are available from the authors.
13. Again, some thoughts on the case where the agent's ability choice is observed publicly are presented in the concluding section.

14. As the proof of Proposition 3 makes clear, we continue to impose only the local incentive compatibility constraints. The corresponding global constraints will be satisfied if $C_{112}(\cdot)$, $C_{122}(\cdot)$ and $\frac{d}{dc} \left\{ \frac{F_e(c|e)}{f(c|e)} \right\}$ are sufficiently small in absolute value $\forall e, c$.
15. Although the agent's ability is not observable to the principal, the principal correctly deduces the agent's self-interested choice of e in equilibrium.
16. Baron and Besanko [1987] and Laffont and Tirole [1987a] also present examples in which both principal and agent prefer the principal to have expanded commitment powers. However, repeated play is central in their models, and they do not allow the agent's ability to be endogenous.
17. With observable ability, these gains for the agent arise when he moves first rather than at the same time as the principal.
18. For expositional reasons, we do not state formally the problems from which e_o^A and e_o^P arise. The problems are the obvious counterparts to the problems [P-A] and [P-P] in the Appendix, except that the agent's ability is observable, and thus can be contracted upon. Also, the proof of Proposition 5 is omitted since it closely parallels the proof of Proposition 3.

APPENDIX

Proof of Proposition 2.

The proof proceeds for the case of the versatile agent. The proof for the case of the idiosyncratic agent follows in analogous fashion.

Let $W(e, c^V)$ denote the single-period maximum expected utility of the principal from dealing with a versatile agent of ability e when the cutoff c realization is c^V , so the agent will pursue alternative opportunities for all $c \in [c, c^V]$. Following the logic of (3.6), it is readily shown that

$$\begin{aligned}
 W(e, c^V) = & \int_{c^V}^{\bar{c}} [V(Q(c)) - C(Q(c), c) \\
 & - \bar{\pi}(c^V) + \frac{1-F(c|e)}{f(c|e)} C_2(Q(c), c)] dF(c|e) - t. \quad (A2.1)
 \end{aligned}$$

Differentiation of (A2.1) and integration by parts as in the proof of Proposition 1 provides

$$\begin{aligned}
 W_1(e, c^V) = & - \int_{c^V}^{\bar{c}} [V'(Q(c)) - C_1(Q(c), c)] Q'(c) F_c(c|e) dc \\
 & - [V(Q(c^V)) - C(Q(c^V), c^V) - \bar{\pi}(c^V)] F_c(c^V|e). \quad (A2.2)
 \end{aligned}$$

When recontracting is possible,

$$V^V(e) = W(e, c^V) + \beta F(c^V|e) [V^V(e) - t], \quad (A2.3)$$

where c^V is chosen optimally. An interior c^V is defined by $\frac{d}{dc^V} V^V(e) = 0$, which implies

$$\begin{aligned}
 - [V(Q(c^V)) - C(Q(c^V), c^V) - \bar{\pi}(c^V) - \beta [V^V(e) - t]] \\
 - [\bar{\pi}'(c^V) + C_2(Q(c^V), c^V)] \frac{1-F(c^V|e)}{f(c^V|e)} < 0, \quad (A2.4)
 \end{aligned}$$

using (A2.1). The inequality in (A2.4) holds because $|\bar{\pi}'(c)| > |\pi'(c)| \quad \forall c \geq c^V$ in the case of the versatile agent.

Differentiation of (A2.3) provides

$$\begin{aligned} & V^{V'}(e) - [1 - \beta F(c^V | e)]^{-1} \left\{ W_1(e, c^V) + \beta [V^V(e) - t] F_c(c^V | e) \right\} \\ & \stackrel{s}{=} - \int_{c^V}^{\bar{c}} [V'(Q(c)) - C_1(Q(c), c)] Q'(c) F_c(c | e) dc \\ & \quad - [V(Q(c^V)) - C(Q(c^V), c^V) - \bar{\pi}(c^V) - \beta [V^V(e) - t]] F_c(c^V | e) < 0. \quad (A2.5) \end{aligned}$$

The second equality in (A2.5) follows from (A2.2). The inequality follows from Lemmas 1 and 3, and (A2.4). ■

Proof of Proposition 3.

The proof proceeds for the case of the versatile agent. The proof for the case of the idiosyncratic agent is analogous.

To begin, the principal's problem when she moves first [P-P] is the following:

$$\text{Maximize}_{Q^P(c), T^P(c), e^P} \int_{\underline{c}}^{\bar{c}} [V(Q^P(c)) - T^P(c)] dF(c | e^P)$$

subject to, $\forall c, \hat{c} \in [\underline{c}, \bar{c}]$:

$$\begin{aligned} & \pi^P(c) \geq \pi(c), \\ & \pi^P(c) \geq \pi^P(\hat{c} | c), \text{ and} \end{aligned}$$

$$e^P \in \underset{e}{\operatorname{argmax}} \left\{ \int_{\underline{c}}^{\bar{c}} \pi^P(c) dF(c|e) - e \right\},$$

where $\pi^P(\ell|c) \equiv T^P(\ell) - C(Q^P(\ell), c)$ and $\pi^P(c) \equiv \pi^P(c|c)$.

Notice that for simplicity, we abstract from any *ex ante* individual rationality constraint that might require the chosen incentive scheme to provide the agent some reservation expected profit level before he chooses his ability level. Because *ex post* individual rationality constraints are imposed, the relevant *ex ante* constraint will automatically be satisfied as long as the information rents that accrue to the agent in equilibrium are large relative to the costs of enhancing ability.

Next, the principal's problem when the agent moves first, [P-A], is:

$$\underset{Q^A(c), T^A(c)}{\operatorname{Maximize}} \int_{\underline{c}}^{\bar{c}} [V(Q^A(c)) - T^A(c)] dF(c|e^A)$$

subject to, $\forall c, \ell \in [\underline{c}, \bar{c}]$:

$$\pi^A(c) \geq \bar{\pi}(c), \text{ and}$$

$$\pi^A(c) \geq \pi^A(\ell|c),$$

where $e^A \in \underset{e}{\operatorname{argmax}} \left\{ \int_{\underline{c}}^{\bar{c}} \pi^A(c) dF(c|e) - e \right\}$, $\pi^A(\ell|c) \equiv T^A(\ell) - C(Q^A(\ell), c)$, and

$$\pi^A(c) \equiv \pi^A(c|c).$$

The necessary conditions for a solution to [P-P] and [P-A] are given in (A3.1) - (A3.3) and (A3.4) - (A3.5), respectively.

$$\begin{aligned}
 V'(Q^P(c)) - C_1(Q^P(c), c) + C_{12}(Q^P(c), c) \frac{1 - F(c|e^P)}{f(c|e^P)} \\
 + \lambda C_{12}(Q^P(c), c) \frac{F_e(c|e^P)}{f(c|e^P)} - 0.
 \end{aligned} \tag{A3.1}$$

$$\int_{\underline{c}}^{\bar{c}} C_2(Q^P(c), c) F_e(c|e^P) - 1 - 0. \tag{A3.2}$$

$$\begin{aligned}
 \int_{\underline{c}}^{\bar{c}} \left\{ [V(Q^P(c)) - C(Q^P(c), c)] f_e(c|e^P) - C_2(Q^P(c), c) F_e(c|e^P) \right. \\
 \left. + \lambda C_2(Q^P(c), c) F_{ee}(c|e^P) \right\} dc - 0.
 \end{aligned} \tag{A3.3}$$

$$V'(Q^A(c)) - C_1(Q^A(c), c) + C_{12}(Q^A(c), c) \frac{1 - F(c|e^A)}{f(c|e^A)} - 0. \tag{A3.4}$$

$$\int_{\underline{c}}^{\bar{c}} C_2(Q^A(c), c) F_e(c|e^A) - 1 - 0. \tag{A3.5}$$

λ is the Lagrange multiplier associated with the lattermost constraint in [P-P].

Suppose $\lambda \geq 0$. Then $V'(Q^P(c)) - C_1(Q^P(c), c) \leq 0 \quad \forall c$ from (A3.1), with strict inequality for some $c \in (\underline{c}, \bar{c})$. After integrating by parts the first term in (A3.3), the equation can be rewritten as

$$- \int_{\underline{c}}^{\bar{c}} \left\{ [V'(\cdot) - C_1(\cdot)] Q^{P'}(c) F_e(\cdot) - \lambda C_2(\cdot) F_{ee}(\cdot) \right\} dc - 0. \tag{A3.6}$$

But this equality cannot hold, because with $\lambda \geq 0$, $F_{ee}(\cdot) \leq 0$, $[V'(\cdot) - C_1(\cdot)] \leq 0$, and $Q^{P'}(c)$

≤ 0 (by arguments identical to those which underlie Lemma 1), the left hand side of (A3.6) is strictly negative. Hence, $\lambda < 0$ by contradiction.

Now suppose $e^A \leq e^P$. Then

$$\frac{1 - F(c|e^P)}{f(c|e^P)} < \frac{1 - F(c|e^A)}{f(c|e^A)} \quad \forall c \quad \text{since} \quad \frac{d}{de} \left\{ \frac{1 - F(c|e)}{f(c|e)} \right\} < 0 \quad \forall c.$$

Now, if $Q^P(c) \geq Q^A(c)$ for some c , then $V'(Q^A(c)) \geq V'(Q^P(c))$ since $V(\cdot)$ is concave.

Therefore, from (A3.1) and (A3.4),

$$\begin{aligned} C_1(Q^A(c), c) - C_{12}(Q^A(c), c) \frac{1 - F(c|e^A)}{f(c|e^A)} &\geq \\ C_1(Q^P(c), c) - C_{12}(Q^P(c), c) \frac{1 - F(c|e^P)}{f(c|e^P)} - \lambda C_{12}(Q^P(c), c) \frac{F_c(c|e^P)}{f(c|e^P)}. \end{aligned} \quad (\text{A3.7})$$

But this is a contradiction if $C_{112}(\cdot)$ is sufficiently small, since $C_{11}(\cdot) \geq 0$ and $\lambda < 0$.

Alternatively, if $Q^A(c) > Q^P(c) \quad \forall c \in [\underline{c}, \bar{c}]$, then $C_2(Q^A(c), c) > C_2(Q^P(c), c) \quad \forall c$ since $C_{12}(\cdot) > 0$. Also, $F_c(c|e^A) \geq F_c(c|e^P) \quad \forall c$ since $e^P \geq e^A$ and $F_{cc}(\cdot) \leq 0$. But then (A3.2) and (A3.5) can't both be satisfied. Thus, $e^P < e^A$. ■

Proof of Proposition 4.

The proof largely parallels the proof of Proposition 3, and so only a brief sketch for the case of the exaggerating agent is presented.

It is straightforward to verify that the necessary conditions for a solution to [P-P] and [P-A] in this binary setting are given in (A4.1) - (A4.4) and (A4.5) - (A4.7), respectively, where Q_j^i is the equilibrium level of output in the solution to [P-i] when c_j is realized.

$$V'(Q_1^P) - C_1(Q_1^P, c_1) = 0. \quad (\text{A4.1})$$

$$V'(Q_2^P) - C_1(Q_2^P, c_2) - \frac{p(e^P) - \lambda^P}{1 - p(e^P)} [C_1(Q_2^P, c_2) - C_1(Q_2^P, c_1)] . \quad (A4.2)$$

$$p'(e^P)[C(Q_2^P, c_2) - C(Q_2^P, c_1)] - 1 = 0. \quad (A4.3)$$

$$p'(e) \left\{ [V(Q_1^P) - C(Q_1^P, c_1)] - [V(Q_2^P) - C(Q_2^P, c_1)] \right\} \\ + \lambda^P p'(e)[C(Q_2^P, c_2) - C(Q_2^P, c_1)] = 0. \quad (A4.4)$$

$$V'(Q_1^A) - C_1(Q_1^A, c_1) = 0. \quad (A4.5)$$

$$V'(Q_2^A) - C_1(Q_2^A, c_2) - \frac{p(e^A)}{1 - p(e^A)} [C_1(Q_2^A, c_2) - C_1(Q_2^A, c_1)]. \quad (A4.6)$$

$$p'(e^A) [C(Q_2^A, c_2) - C(Q_2^A, c_1)] - 1 = 0. \quad (A4.7)$$

λ^P is the Lagrange multiplier corresponding to the agent's choice of e^P in the binary version of [P-P].

If $\lambda^P < 0$, then (A4.4) requires $V(Q_1^P) - C(Q_1^P, c_1) < V(Q_2^P) - C(Q_2^P, c_1)$, which (A4.1) reveals to be impossible. Corresponding logic ensures $\lambda^P \neq 0$.

Now suppose $e^P \leq e^A$. If $Q_2^A \leq Q_2^P$, then a direct comparison of (A4.2) and (A4.6) reveals a contradiction, provided $C_{112}(\cdot) \geq 0$ or $C_{112}(\cdot) < 0$ and $|C_{112}(\cdot)|$ is sufficiently small. Alternatively, if $Q_2^P > Q_2^A$, then (A4.3) and (A4.7) cannot both hold. Hence, $e^A > e^P$.

With $e^A > e^P$, $p'(e^P) > p'(e^A)$. Therefore, $Q_2^P > Q_2^A$ from (A4.3) and (A4.7), since $C_{12}(\cdot) > 0$.

Finally, letting π^i denote the equilibrium expected profit of the agent when party i ($= P$ for principal and A for agent) moves first, we have:

-A7-

$$\begin{aligned}\pi^P &= p(e^P)[C(Q_2^P, c_2) - C(Q_2^P, c_1)] - e^P \\ &> p(e^A)[C(Q_2^P, c_2) - C(Q_2^P, c_1)] - e^A \\ &> p(e^A)[C(Q_2^A, c_2) - C(Q_2^A, c_1)] - e^A \\ &= \pi^A.\end{aligned}\tag{A4.8}$$

The equalities in (A4.8) follow from straightforward substitution into the agent's objective function. The first inequality in (A4.8) holds because e^P maximizes the agent's expected profits in the solution to [P-P]. The last inequality holds because $Q_2^P > Q_2^A$.

Of course, the principal's expected utility is strictly higher in the solution to [P-P] since the solution to [P-A] is a feasible solution to [P-P], but not the optimal one. ■

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