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Source: *The RAND Journal of Economics*, Vol. 35, No. 2 (Summer, 2004), pp. 356-372

Published by: [Blackwell Publishing](#) on behalf of [The RAND Corporation](#)

Stable URL: <http://www.jstor.org/stable/1593695>

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# Auditing and property rights

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and

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*Third-party audit provides incentives to an agent whose actions affect the value of an asset. When audit intensity and outcome are unverifiable, we show that with interim-participation constraints the optimal mechanism may use only the auditor's report, disregarding the agent's information. Furthermore, the auditor obtains the asset and the agent a monetary compensation, when a high asset value is reported. This suggests regulating renewable resources or utility networks by giving entrants the option to buy the right to use the asset at a predetermined price, and financially rewarding incumbents for good performance.*

## 1. Introduction

■ The quality of information is crucial for designing efficient incentive schemes. “Better” information allows the design of “better” incentive schemes that reduce the inefficiencies linked to the informational advantage of agents. A large literature has analyzed how audit structures modify the form and the degree of inefficiency of employment contracts, regulatory contracts, tax schedules, or financial contracts. It is generally assumed that the audit technology produces verifiable information.

This approach has led to important insights. It is nevertheless quite restrictive in practice. In most cases, audit is not performed by the principal directly, but rather by auditors (who are either employees of the firm or employees of firms that specialize in audit services) who may fail to act in the interest of their principals (recent cases in the United States are a dramatic illustration of this).

That auditors may need to be given incentives to *acquire* and *reveal* information is an issue as-yet unexplored. Such a situation is particularly relevant when auditing does not generate hard information and when the auditor cannot produce evidence that he has gathered information. An example is the repeated management of an asset (such as timber rights, or rights to manage an

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This is a revised version of CEPR DP no. 2777, February 2001. For helpful comments, the authors wish to thank Christian Laux, Ethan Kaplan, Jacques Lawarée, Michele Piccione, seminar participants at Brunel University, London School of Economics, Loughborough University, Royal Holloway, and South Bank University, as well as conference participants at the 8th World Congress of the Econometric Society in Seattle (2000). Special thanks are due to Editor Raymond Deneckere and two anonymous referees for very helpful suggestions. The second author benefited from the financial support of the Communauté française de Belgique (projet ARC 98/03-221) and EU TMR Network contract no. FMRX-CT98-0203.

electrical network): past users take actions that affect the future value of the asset, and audit gives information about this future value. Another example is information gathered by investors prior to a takeover or a merger offer. In both cases, the estimate of the future value of the asset is the result of computations by experts and is not generally directly observable by third parties.

In this article we analyze a model in which audit is needed to provide incentives to an agent who exerts effort into a productive asset. We depart from standard models of audit in two ways. First, we consider the case where neither the audit intensity nor the audit outcomes are observable by third parties and audit produces “soft” information.<sup>1</sup> This implies that the principal faces three incentive problems: first, the *ex ante* moral hazard problem of inducing higher productive effort from the auditee; second and third, the *ex post* problems of inducing the auditor to acquire and truthfully reveal information. Second, we assume that the auditee and the auditor participate at any time in contracts only if their continuation expected utility is nonnegative; such a lower bound can be achieved if agents have limited liability or can “run away.”<sup>2</sup> This assumption introduces a nontrivial tradeoff between interim individual rationality and incentive compatibility for information revelation.

We obtain two results. First, we show that when only the auditor’s information is used in contracting, the optimal contract takes the form of an option for the auditor to buy the right to use the asset at a given price, and for the auditee to receive a monetary compensation whenever the right to use the asset is transferred to the auditor. Hence, in contexts with soft information, property rights become a crucial element for information acquisition and incentives. Second, we show that this result is robust against the possibility of correlated information between the auditee and the auditor in that the principal may find it optimal to *ignore* the auditee’s information in designing contracts.

We use a standard agency model with auditing. An agent (incumbent *I*) exerts effort into a productive asset, owned by the principal. Higher effort increases the probability that the future monetary value of the asset is high; higher asset values are also associated with higher nonmonetary benefits for the principal. Information about future value of the asset can be used in contracts with *I* and could improve his incentives to provide effort. If the principal relies only on *I*’s information, the incentive-compatibility problem of inducing *I* to reveal his information about future value makes this information valueless for contracting. However, by relying on the information collected by another agent *A* (also referred to as the auditor), the principal may improve on contract efficiency. We assume that *I* has access to a perfect signal of the future value of the asset whereas *A* has access to an imperfect signal that reveals the future value of the asset with a probability equal to the audit intensity but does not reveal anything with the complementary probability.<sup>3</sup>

The result that audit improves the principal’s payoff only if the auditor has the option of obtaining rights on the future value of the asset follows from the need to create incentives for information acquisition *and* truthful information revelation. Having claims on the future value of the asset, *A* will not take the risk of paying too much for a mediocre asset and thus will become informed and truthfully reveal his information. This information can then be used to create incentives for *I* by giving him a monetary payment when the auditor announces that the future value of the asset is high. This result holds whenever contracts rely on *A*’s information only. (In our two examples, note that claims on future value of the asset are indeed key for creating information acquisition: if the potential licensee is certain not to get the license, he has no incentive to invest in information gathering; if the investor is certain not to get control of the firm, incentives to invest in information gathering are destroyed.)

<sup>1</sup> The assumption that *all* audit information is soft is obviously extreme, but it enables us to highlight in a stark way the interplay between the moral hazard and the revelation problems for the auditor.

<sup>2</sup> In the two examples of licensing and takeover, this assumption is empirically relevant. In the licensing example, bidding for licenses is voluntary and firms may decide not to bid in certain contingencies. In the takeover example, the raider may decide not to go ahead with the takeover and the shareholders not to accept the offer of the raider.

<sup>3</sup> Hence *I*’s information is quite valuable to the principal, and this makes it more difficult to show that the principal optimally ignores it.

When both  $A$  and  $I$  have access to a signal about the future value of the asset, relying only on the information of the auditor may be suboptimal for the principal. It is indeed well known that relying on the information of both agents will effectively make information verifiable: the principal can ask both agents to reveal their information and punish them if their announcements are incompatible with the correlated information structure. But when agents cannot commit to stay in the relationship, the ability to punish is limited, and it is not clear anymore that there is a strict benefit from using  $I$ 's information in addition to  $A$ 's information.

We verify this conjecture first in the situation where audit intensity and audit outcomes are verifiable;  $I$ 's incentive-compatibility conditions for information revelation imply that whenever audit fails,  $I$  obtains full claims on the future value of the asset, and such a contract can be replicated without relying on  $I$ 's information. Hence,  $I$ 's information is not useful for the principal in this context.

More surprisingly, we show that when the audit intensity and the audit outcome are not observable, it may be *strictly optimal not to* rely on  $I$ 's information. Ignoring  $I$ 's information implies that when audit fails, the distribution on states has less precision than if  $I$ 's information is also available. This generates two effects: first, the problem of revelation of information by  $A$  is worsened, but, second,  $A$ 's interim participation constraint is easier to satisfy (since it must be satisfied in expectation, whereas when the allocation reveals  $I$ 's information, it must be satisfied pointwise). When the second effect dominates the first, it is optimal to indeed ignore  $I$ 's information in the contract.

Our results have direct implications for the design of regulations on the allocation of rights to the use of assets, such as renewable resources (forests) or utility networks (electricity, water, telecoms). Consider for instance the licensing of the right to develop, maintain, and use (and, hence, collect revenues from consumers) electricity networks. While periodic auctions are indeed held for these rights, it is not the case that the incumbent receives a payment when the right goes to another party. Our article suggests that such a simple modification of auctions would improve on dynamic efficiency.<sup>4</sup> Moreover, since transfers to the incumbent can be financed by the entrant (auditor), the principal may not need a large amount of funding to induce auditing and discipline the incumbent; this is obviously important for less-developed countries where fiscal considerations are key. Interestingly, this is exactly what the World Bank has implemented in Argentina for electricity transmission and distribution rights: concessions are obtained for 95 years, but the *management* of the contract is subject to bidding every 10 years. Firms bid for the majority of the shares of the company; if the price offered by the incumbent is the highest, he keeps the property, otherwise the highest bidder has to pay the price bid to the incumbent and becomes the new majority owner. As far as we know, Argentina is the only country where such concession contracts are in effect.<sup>5</sup>

The rest of the article is organized as follows. In Section 2 we discuss our contribution within different strands of the literature. We introduce the model in Section 3 and consider the optimal contract in the absence of auditing in Section 4. In Section 5 we introduce auditing but assume that the auditor's effort and the information he collects are verifiable, and we show that  $I$ 's information has no value. In Section 6 we discuss the optimal mechanism in the presence of auditing when the principal can observe neither the audit intensity nor the audit outcome. We also present the one-sided revelation case, in which the principal relies only on the information provided by the auditor; we show that audit is beneficial when  $A$  obtains rights on the use of the asset. After that, we allow for two-sided revelation where both the incumbent's and the auditor's information is used in the contract, and we show that  $I$ 's information may be of no value. In Section 7 we summarize our conclusions. All proofs missing from the text are in the Appendix.

<sup>4</sup> Our result also suggests how reservation prices in auctions may affect information transmission from the potential buyer to the seller.

<sup>5</sup> We thank Antonio Estache for pointing out this example to us; a description of the concession contract is in Rodriguez-Pardina, Helou, and Estache, (1998).

## 2. Links to the literature

■ **Auditing.** Since the seminal article by Baron and Besanko (1984), a large literature has studied the value of auditing for reducing informational rents. The possibility that auditors themselves are subject to opportunist behavior has been extensively acknowledged (see, for example, Tirole, 1986, 1992; and Kofman and Lawarrée, 1993). However, the main focus of this literature remains the possibility of collusion between the agent and the auditor, rather than the incentive problem that arises if auditing effort is unobservable.<sup>6</sup> Further, it is commonly assumed that auditing generates hard information. To the best of our knowledge, our article is the first to develop a model of audit where the principal can observe neither the intensity nor the outcome of the audit and where auditing generates soft information.

□ **Second sourcing.** There is an extensive literature on second sourcing in dynamic auctions tracing back to the work of Anton and Yao (1987). One of the main arguments in favor of second sourcing is that competition may reduce the incumbent's rent (e.g., Demski, Sappington, and Spiller, 1987). However, in the presence of incumbent moral hazard this positive effect must be balanced with the negative effect on the incumbent's incentives (e.g., Laffont and Tirole, 1988). In contrast, we show that second sourcing may ease the moral hazard problem because it can be used as an *information-collection device* to discipline the incumbent.

□ **Value of communication.** Work on communication infrastructure has assumed exogenous constraints on the ability of agents to communicate in order to derive the optimality of restricted forms of communication in organizations (see, for instance, Bolton and Dewatripont, 1994; Green and Laffont, 1987; Radner and Van Zandt, 1995; Melumad, Mookherjee, and Reichelstein, 1997; Legros and Newman, 1999, 2002). As far as we know, the idea that the optimal design of communication flows reflects interim participation constraints is new.<sup>7</sup>

□ **Costly information gathering and mechanism design.** Another strand in the literature analyzes the optimal acquisition of information by an agent. Typical questions concern the timing of information gathering (Sobel, 1993), how to deal with the possibility of ignorance (Lewis and Sappington, 1993), and the benefit to the principal of having the agent gather information before taking action (Lewis and Sappington, 1997; Crémer, Khalil, and Rochet, 1998).<sup>8</sup> Our model departs in a significant way from this literature, since information is used to evaluate the performance of another agent. This implies that to induce information acquisition and truthful revelation, the payoff of the auditor needs to be *contingent on the real state*, which in turn suggests the desirability of giving property rights to the auditor.

## 3. The model

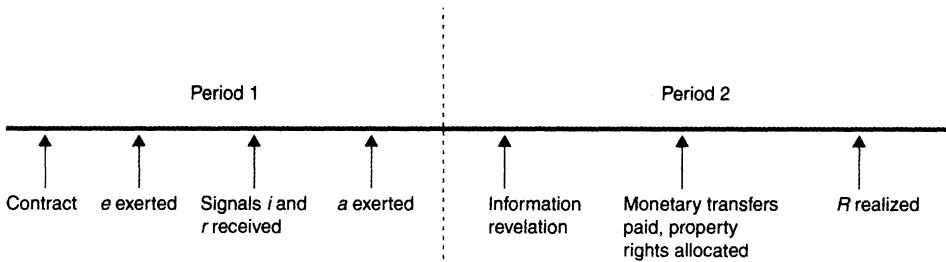
■ Consider the following standard agency model. An agent (incumbent  $I$ ) has the current right to use an asset. The future value of the asset is indexed by  $R^i$ , where  $R^i \in \{R^L, R^H\}$  and, for simplicity,  $R^i$  is also the future revenue the asset can generate when it is used for production (to simplify, we ignore first-period revenues and related transfers). The timing of the game is summarized in Figure 1.

<sup>6</sup> One exception is Demski and Sappington (1987), where the regulator (our  $A$ ) needs to be given incentives to audit the regulated firm (our  $I$ ) but, contrary to our model, the firm's performance is observable and can be used to evaluate the regulator's performance. Another exception is Baliga (1999) who considers monitoring and collusion with soft information.

<sup>7</sup> Note that our result does not conflict with the intuition gained from the revelation principle that there is no loss in assuming that both agents reveal their information truthfully. Indeed, the revelation principle does not imply that the information of one party *must be effectively used* in contracting, which is the nature of our result.

<sup>8</sup> Lewis and Sappington (1997) also study the benefit from separating planning (i.e., information gathering) and production.

FIGURE 1



There are two periods. In period 1,  $I$  takes an unobservable action  $e$ , at cost  $e$ , that modifies the probability of the high value in period 2,  $\Pr(R^H) = v(e)$ , and we assume

$$v'(e) \geq 0, \quad v''(e) \leq 0, \quad \frac{v(e)}{v'(e)} \text{ convex.}$$

Thus, there is an ordering on the choice of technology (or care, etc.)  $e$  such that on one side larger values of  $e$  make the revenues from the asset “higher” but also cost more to the agent. The assumption that  $v(e)/v'(e)$  is convex ensures that the principal’s program is concave in  $e$ ; a sufficient condition for it to hold is  $v'''(e) \leq 0$ .

The mean revenue in period 2 is

$$\rho(e) = v(e)(R^H - R^L) + R^L,$$

with  $\rho'(e) > 0$  and  $\rho'' \leq 0$ , since  $v'(e) \geq 0$  and  $v''(e) \leq 0$ .

The principal obtains unobservable nonmonetary benefits from the asset (for instance, a forest in “good health” brings social benefits that are difficult to measure). To simplify, we assume that if the future value is  $R^i$ , the benefit is  $S^i$ , with  $S^H - S^L > 0$ . Defining the mean benefit as

$$\sigma(e) = v(e)(S^H - S^L) + S^L,$$

it follows that  $\sigma'(e) > 0$  and  $\sigma''(e) \leq 0$ ;  $I$ ’s effort generates a positive externality for the principal.

At the end of period 1, a signal  $r$  can be received by  $I$  and by another agent  $A$  (the auditor);  $r$  takes values in  $\{L, H, N\}$ . The incumbent  $I$  has access to a perfectly informative signal technology:  $\Pr(r = i \mid R = R^i) = 1$  for  $i = L, H$ . The auditor  $A$  who exerts audit effort  $a$  at cost  $C(a)$  has access to an imperfect signal technology, by which for each  $i$ ,  $\Pr(r = i \mid R = R^i) = a$  and  $\Pr(r = N \mid R = R^i) = 1 - a$ ; that is, with probability  $a$  the auditor learns the future value of the asset and with probability  $1 - a$  he does not learn it. We assume  $C'(a) > 0$ ,  $C''(a) \geq 0$ ,  $C'(0) = 0$ , and  $C'(1) = \infty$ . The signals received by  $I$  and  $A$  are private and “soft” in the sense that there is no hard piece of evidence proving that a particular signal has been received. The principal does not observe  $R$ . In period 2, the agent who has the right to use the asset obtains the realized value  $R^i$ , assumed unobservable.<sup>9</sup> The principal has limited funds,  $z \geq 0$ , and maximizes the expected nonmonetary benefit net of the transfers paid to the agents (which can be negative);  $I$  and  $A$  are risk neutral and maximize their utility functions. Further, at the beginning of period 1 the principal can commit to any long-term mechanism specifying the contractual conditions applying to periods 1 and 2.

We assume that  $I$  and  $A$  can turn down any allocation at the beginning of period 2, so an interim participation constraint, ensuring a nonnegative utility to each agent conditioned on the

<sup>9</sup> In our risk-neutral world,  $R^i$  can also be interpreted as a probability distribution over future returns  $Y$ . We assume that the agent has private knowledge of the distribution and the returns. If the actual returns  $Y$  are observable by the principal, contracts can be made contingent on both the announced  $R^i$  and the realized  $Y$ . However, this would not affect our qualitative results.

information available, must hold at the beginning of period 2. We also assume that the principal is unable to fully extract the agents' second-period rent (if any) by charging entry fees in period 1. The notion that second-period rents matter can be rationalized in many ways. For example, agents might discount future payoffs more than the principal; this creates a gap between the agents' willingness to pay at the beginning of period 1 and the discounted cost of the second-period rents for the principal. It is also possible that at the signing of the contract, agents have investment opportunities that are forgone once period 1 is over; in this case the agents' willingness to pay is the expected rent net of the opportunity cost of the forgone investment. Finally, agents may be protected by limited liability, which is generally interpreted either as a constraint on the transfers between the principal and the agents or as a constraint on the utility of the agents.

For simplicity, we model the assumption that second-period rents matter by imposing a nonnegative constraint on the first-period transfers between the principal and the agents, and we disregard discount rates. As a result, the principal is unable to extract any of the second-period rents, and we can disregard first-period transfers throughout. This extreme assumption allows us to capture in a simple way the cost of second-period rents for the principal and has no qualitative impact on the characteristics of the optimal contract or, in general, on our results.

Let  $(x, s)$  denote, respectively, the probability that  $I$  obtains the right to use the asset and the monetary transfer he receives from the principal (which can be negative) in period 2. Let  $(y, t)$  be the corresponding values for  $A$ .  $I$ 's and  $A$ 's realized payoffs in period 2 are then given by

$$\begin{aligned} V &= xR + s \\ U &= yR + t. \end{aligned}$$

Thus, *ex ante*,  $I$ 's payoff is  $EV - e$ , and  $A$ 's payoff is  $EU - C(a)$ , where  $E$  is the expectation operator.

The payoff of the principal is

$$S - (s + t) \equiv S + (x + y)R - (V + U),$$

where use has been made of the definitions  $V$  and  $U$ .

As a benchmark, consider the case where  $e$  and  $R$  are verifiable. Here, auditing does not occur (since it has no value and is costly), the principal reimburses  $I$  for his cost of effort  $e$ , and the optimal level of effort maximizes  $\sigma(e) + \rho(e) - e$ , yielding

$$\sigma'(e^{FB}) + \rho'(e^{FB}) = 1. \tag{1}$$

The agent exerts effort so as to internalize the effect on the expected revenue from the asset and the externality that effort generates to the principal.

In the next two sections we shall discuss two further benchmarks that will be useful in our analysis. First, we consider the optimal contract to  $I$  in the absence of third-party auditing. Second, we introduce auditing but assume that both the auditor's effort,  $a$ , and the information he collects,  $r \in \{L, H, N\}$ , are verifiable.

#### 4. No auditing

■ Since the nonmonetary payoff ( $S^i$ ) of effort is not part of the incumbent's utility function, if  $I$  retains the revenues from the asset in period 2, he will underprovide effort with respect to what is optimal. Indeed, if  $I$  retains full property rights in period 2, he chooses  $e$  in period 1 so as to maximize  $\rho(e) - e$ , yielding

$$\rho'(e^M) \equiv v'(e^M)\Delta = 1, \tag{2}$$

where  $\Delta \equiv R^H - R^L$ . Comparing (2) to (1), it is immediate that  $e^M < e^{FB}$ .

Could the principal benefit from making contracts contingent on information revealed by  $I$ ? Let  $(x^i, s^i)$  be such a contract when  $I$  reports  $i \in \{L, H\}$ . Thus,  $I$ 's interim payoff is  $V^i = x^i R^i + s^i$  whenever he truthfully reveals his signal. At the time of making productive effort,  $I$ 's expected rent is

$$v(e)V^H + (1 - v(e))V^L - e,$$

and he chooses effort that solves

$$v'(e)(V^H - V^L) = 1. \tag{3}$$

Thus, effort is higher the greater the difference in the payoffs between the high and low state; further, only if this difference is greater than  $\Delta$ , effort higher than  $e^M$  can be generated (from (2)).

For  $I$  to truthfully reveal his information, incentive compatibility requires

$$\begin{aligned} V^H &\geq V^L + x^L \Delta \\ V^L &\geq V^H - x^H \Delta, \end{aligned}$$

which implies

$$x^H \geq x^L \tag{4}$$

$$x^H \Delta \geq V^H - V^L \geq x^L \Delta. \tag{5}$$

In light of (3), (4), and (5), effort is maximized at the minimum cost for the principal when  $x^H = x^L = 1$ ,  $V^H = \Delta$ , and  $V^L = 0$ . This yields effort  $e^M$  that solves (2). Thus, without auditing, the information of  $I$  has no value for contracting.

Note that since  $-s^i = x^i R^i - V^i$ , at the optimal contract that ensures effort  $e^M$ , the principal extracts the expected revenue net of the *ex post* rent of  $I$ , given by  $v(e^M)\Delta \equiv v(e^M)/v'(e^M)$  in light of (2). Thus the principal's payoff is  $\sigma(e^M) + \rho(e^M) - [v(e^M)/v'(e^M)]$ . We shall assume throughout that the principal wishes to induce a higher level of effort than  $e^M$ , despite the resulting cost in expected rent. We formalize this assumption below.

*Assumption 1.*  $\sigma'(e^M) + \rho'(e^M) - 1 - (d/d e)[v(e^M)/v'(e^M)] > 0$ .

### 5. Verifiable auditing

■ Suppose now that the principal asks another agent ( $A$ ) to collect information on the future value of the asset at the end of period 1. By assuming that the auditing intensity  $a$  and the information obtained in the audit are verifiable, we can derive an upper bound on the value of audit and information acquisition.

The contracts offered to  $I$  and  $A$  can now be made contingent on the result of audit. However, allocations that improve the principal's payoff could be achieved by also asking  $I$  to reveal information about  $R^i$ . We will first ignore this possibility and focus only on the value of audit information; later we will show that when agents must have nonnegative interim payoffs, the information of  $I$  has no value.

A contract to  $I$  is an allocation  $(x^r, s^r)$ , where  $r \in \{L, H, N\}$ . Let  $V^{ir}$  be the utility of  $I$  when he receives signal  $i$  while the auditor receives signal  $r$ , that is  $V^{ir} = x^r R^i + s^r$ . At the time effort  $e$  is taken, the expected utility of  $I$  is

$$a[v(e)V^{HH} + (1 - v(e))V^{LL}] + (1 - a)[v(e)V^{HN} + (1 - v(e))V^{LN}] - e, \tag{6}$$

and the equilibrium effort solves

$$v'(e)[a(V^{HH} - V^{LL}) + (1 - a)(V^{HN} - V^{LN})] = 1. \tag{7}$$

We note that  $V^{HN} - V^{LN} = x^N \Delta$  is bounded above by  $\Delta$  (since  $V^{LN} \geq 0$ ), and  $V^{HH} - V^{LL}$



is bounded above by  $z + R^H$  (since  $V^{LL} \geq 0$ ). We show in the Appendix that it is optimal to set these values to their upper bounds. Hence, for any  $a > 0$ , auditing helps to create incentives, since  $v'(e^M)[a(z + R^H) + (1 - a)\Delta] > v'(e^M)\Delta = 1$ , and the equilibrium choice of  $e$ , given the anticipated  $a$ , is greater than  $e^M$  by concavity of  $v(e)$ .

The equilibrium condition can be written

$$av'(e)(z + R^L) + \rho'(e) = 1, \text{ or,} \tag{8}$$

$$e = \phi(a), \text{ where}$$

$$\phi(a) \stackrel{\text{def}}{=} (v')^{-1} \left( \frac{1}{a(z + R^L) + \Delta} \right). \tag{9}$$

Since  $a$  is assumed to be verifiable, the principal maximizes his payoff subject to (8) and to the cost  $C(a)$  of auditing.

Since  $I$  receives a perfect signal  $i \in \{L, H\}$  of the future value of the asset, it might be beneficial for the principal to use both the audit information and  $I$ 's information in contracting. Let  $(x^{ir}, s^{ir})$  be the contract that is offered when  $I$  reveals that the signal is  $i \in \{L, H\}$  and  $A$  reveals that he received signal  $r \in \{L, H, N\}$ . Let  $V^{ir} = x^{ir}R^i + s^{ir}$  be the utility of  $I$  when announcements are truthful and equal to  $(i, r)$ . With probability  $a$ ,  $I$  and  $A$  obtain the same signal, therefore incentives for  $I$  to misreport his signal are minimized when  $V^{ir} = 0$  whenever  $r \in \{L, H\}$  and  $i \neq r$ . Since, with probability  $1 - a$ , the principal will not infer from messages  $(i, N)$  that  $I$  misreported, an incentive problem remains. Incentive compatibility requires that the following two conditions hold:

$$aV^{HH} \geq (1 - a)x^{LN}\Delta - (1 - a)(V^{HN} - V^{LN}) \tag{10}$$

$$aV^{LL} \geq (1 - a)(V^{HN} - V^{LN}) - (1 - a)x^{HN}\Delta, \tag{11}$$

in which case  $I$  chooses  $e$  as in (7). With respect to the situation with one-sided information revelation, the incentive-compatibility constraints do not impose a cost on contracting (the previous contract satisfies the conditions, since  $I$ 's information is not used). The principal could potentially be better off now because the information transmitted by  $I$  allows contracts when  $A$  observes nothing ( $r = N$ ) to be made contingent on  $I$ 's information. However, we show below that there is no value in having this flexibility, since, by incentive compatibility,  $\Delta$  is the optimal difference in payoffs when  $A$  reports  $N$ .

From (7), for a given difference  $V^{HN} - V^{LN}$ , effort is maximum when the difference  $V^{HH} - V^{LL}$  is the largest. Suppose that  $V^{HN} - V^{LN}$  is greater than  $\Delta$ . From (10),  $V^{HH}$  can take any nonnegative value, whereas by (11),  $V^{LL}$  is bounded below by the right-hand side. In fact, since decreasing  $V^{LL}$  increases the gap  $V^{HH} - V^{LL}$  and the effort of  $I$  while it reduces rent payments, (11) must bind. Substituting the value of  $V^{LL}$  in (7), we obtain  $v'(e)(aV^{HH} + (1 - a)x^{HN}\Delta) = 1$ ; since  $V^{HN} - V^{LN}$  does not appear in this expression and since giving rents is costly for the principal, it is optimal to decrease  $V^{HN}$  up to the point where  $V^{HN} - V^{LN} = \Delta$ . Note that by doing so, (10) and (11) continue to hold. We give the complete argument and establish the following result in the Appendix.

*Proposition 1.* Under verifiable auditing, the optimal contract is achieved by relying on  $A$ 's information only. The optimal contract gives property rights to  $I$  ( $x^r = 1$  for all  $r = L, H, N$ ) and  $V^{LL} = V^{LN} = 0$ ,  $V^{HH} = z + R^H$ , and  $V^{HN} = \Delta$ . Productive effort  $e^*$  and auditing effort  $a^*$  are such that ( $\phi$  is defined in (9))

$$a^*v'(e^*)(z + R^L) + \rho'(e^*) = 1 \tag{12}$$

$$\phi'(a^*) \left[ \sigma'(e^*) + \rho'(e^*) - \frac{d}{de} \left( \frac{v(e^*)}{v'(e^*)} \right) \right] - C'(a^*) = 0, \tag{13}$$

where  $e^{FB} > e^* > e^M$  and  $a^* > 0$ .

Note that auditing is valuable for providing incentives to  $I$  even if the principal lacks funds to motivate the agent (i.e.,  $z = 0$ ). This is because auditing by  $A$  generates information that allows the difference between  $I$ 's payoff in the high and the low state (when the report is informative) to increase up to  $R^H$  (rather than  $\Delta$ ).

### 6. Unobservable audit

■ In the previous sections we have shown that the presence of interim participation constraints makes  $I$ 's information—even if it is of a better quality than information available via audit—not useful in the design of incentive contracts for  $I$ , while audit information is. In this section we consider the possibility that the auditor himself needs to be motivated to exert effort and to provide reliable auditing. We shall show that to induce  $A$  to acquire information, it may be necessary to give him property rights on the future asset returns.

To see this, we proceed as follows. First, we assume that the principal does not ask  $I$  to reveal his information but relies only on the information collected by  $A$ . This is the “one-sided revelation problem,” which is similar in nature to the case where  $I$  is not informed at all. Within the one-sided revelation case we shall proceed in two steps: we first discuss the revelation problem of  $A$ , assuming that he has information; then we analyze his incentives to acquire information. This allows us to highlight the interplay between the adverse-selection and moral hazard problems of  $A$ . We then consider the “two-sided revelation” case, where both  $I$  and  $A$  reveal their information to the principal and this information is effectively used in contracting. This presentation of the results emphasizes the costs and benefits of using more information in the optimal contract in the presence of interim participation constraints.

□ **One-sided revelation.** *The auditing problem.* Consider the revelation problem of  $A$ . Standard mechanism design tells us that we can restrict attention to a direct revelation mechanism that specifies property rights and monetary transfers as a function of the state  $A$  announces,  $r \in \{L, H, N\}$ .<sup>10</sup> Let  $(y^r, t^r)$  be the probability and the side payment maps for  $A$  and  $(x^r, s^r)$  be the probability and the side payment maps for  $I$  when the announced signal is  $r$ . We denote by  $U^r = y^r R^r + t^r$   $A$ 's payoff when he reports  $r$  truthfully. By interim rationality, the constraint  $U^r \geq 0$  needs to hold for all  $r \in \{L, H, N\}$ .

Let  $\hat{e}$  be the effort that  $A$  believes  $I$  took in the first period. When  $A$  observes  $r$  and reveals  $k \in \{L, H, N\}$ , he will be given, with probability  $y^k$ , an asset that is worth  $R^r$  (when  $r = N$  it is worth  $\rho(\hat{e})$ ), paying at most  $y^k R^k$  (since the interim participation constraint implies  $t^r \geq -y^r R^r$ ). This yields a rent of at least  $U^k + y^k(R^r - R^k)$ . Hence,  $A$  has an incentive to underreport his information in order to obtain property rights for less than they are worth. Incentive-compatibility conditions are<sup>11</sup>

$$U^H \geq U^L + y^L(R^H - R^L) \tag{14}$$

$$U^H \geq U^N + y^N(R^H - \rho(\hat{e})) \tag{15}$$

$$U^L \geq U^H - y^H(R^H - R^L) \tag{16}$$

$$U^L \geq U^N - y^N(\rho(\hat{e}) - R^L) \tag{17}$$

$$U^N \geq U^H - y^H(R^H - \rho(\hat{e})) \tag{18}$$

$$U^N \geq U^L + y^L(\rho(\hat{e}) - R^L). \tag{19}$$

<sup>10</sup> Since effort is sunk when revelation takes place, and since there is no renegotiation, there is no value in asking  $A$  to reveal the amount invested in information gathering.

<sup>11</sup> The first two conditions are for the case where  $A$  observes  $H$  and deviates to  $L$  or  $N$ , the next two are for the case where  $A$  observes  $L$ , and the last two are for the case where  $A$  observes  $N$ .

Note the relationship between the property rights to  $A$  in the different cases. From (14)–(19), a monotonicity condition needs to hold:

$$y^H \geq y^N \geq y^L. \quad (20)$$

This is important because it implies that if the principal allocates property rights to  $A$ , then  $A$  will have property rights in state  $H$ , that is, when ownership incentives are most important to motivate  $I$ . However, truthful revelation per se does not require that  $A$  receive property rights with positive probability. Indeed, truthful revelation could be induced by simply giving  $A$  the same monetary compensation in all states. This would yield  $U^H = U^L = U^N$ .<sup>12</sup> As well shall see, the need to allocate property rights to  $A$  comes from the combination of the nonobservability of  $A$ 's effort *and* the fact that the information he collects is private and unverifiable. With monetary compensations only,  $A$  would not acquire information and his report would not be informative.

To see this, consider the moral hazard problem of  $A$ . At the time of choosing auditing effort,  $A$  maximizes his expected payoff, given by

$$a [v(\hat{e})U^H + (1 - v(\hat{e}))U^L] + (1 - a)U^N - C(a), \quad (21)$$

thus he chooses the level of  $a$  that solves

$$v(\hat{e})U^H + (1 - v(\hat{e}))U^L - U^N = C'(a). \quad (22)$$

Note that  $a$  increases with  $A$ 's payoff when his report is informative (i.e.,  $k \in \{L, H\}$ ) and decreases with  $A$ 's payoff when he observes nothing (i.e., reports  $N$ ). To induce information acquisition,  $A$  needs to be given a rent when his report is informative that is greater than what he obtains when his report is uninformative. Property rights are the only way to provide a rent that satisfies this condition and at the same time allows truthful revelation of information. Indeed, if only monetary transfers were used,  $A$  would always report the signal  $k$  that maximizes the associated transfer and exert no auditing effort. The following result establishes the necessity of property rights for information acquisition.

*Proposition 2.* When the principal relies only on the information provided by the auditor,

- (i) the auditor exerts positive effort only if he has property rights when he reports that the asset has high value ( $y^H > 0$ ), and
- (ii) in this case, the auditor pays a price for these property rights that is below the real value of the asset ( $y^H R^H$ ) but is at least equal to its expected value ( $y^H \rho(\hat{e})$ ).

$A$  needs to receive property rights when he reports good news (i.e.,  $H$ ) at some posted price such that if the future value of the asset is really  $R^H$ , then  $A$  pays less for the asset than what it is worth ( $y^H R^H$ ). This constitutes the reward from gathering information. At the same time, though, it is optimal to set this posted price at least equal to the expected value of the asset (more precisely,  $y^H \rho(\hat{e})$ ), so that the risk of paying a lot for a mediocre asset makes  $A$  prefer to become informed rather than blindly report  $H$ . Thus, the sale of the right to use the asset at a posted price is an optimal device to generate information: the willingness to buy reveals the information about the future value of the asset.

Since incentives for  $A$  to acquire information come from the possibility of obtaining the asset at a posted price between  $y^H \rho(\hat{e})$  and  $y^H R^H$ ,  $A$ 's reward from auditing effort is bounded above under one-sided revelation.

*Corollary 1.* Under one-sided revelation, for each level of productive effort  $\hat{e}$ , there exists a maximum level of audit intensity, denoted by  $a_{\max}(\hat{e})$ , that the principal can implement, where

$$v(\hat{e})(1 - v(\hat{e}))\Delta = C'(a_{\max}(\hat{e})). \quad (23)$$

<sup>12</sup> This under the standard assumption that, when indifferent,  $A$  reports the truth.

*The optimal contracts under one-sided revelation.* Let us summarize the results obtained so far. First, auditing information is valuable to motivate  $I$  to exert  $e > e^M$  (Section 5), but this information cannot be acquired by simply hiring an auditor: property rights to the auditor are needed (Proposition 2). Thus, the market for the right to use the asset plays two roles: it allocates the asset to potential buyers and it generates information that can be used to discipline whoever exploited the asset in the past. Further, in this market a bias in favor of  $A$  needs to be created when the future value of the asset is high ( $R^H$ ). But this implies that “better” state-contingent monetary compensations to  $I$  come at the cost of reduced ownership incentives. Taking away the asset from  $I$  when the future value of the asset is high, *ceteris paribus*, reduces effort. In light of this, we now analyze whether the use of sales as an information-collection device to motivate  $I$  is indeed desirable.

Consider the principal’s maximization problem when he wishes to induce information acquisition from  $A$  and use the information to motivate  $I$ ,

$$\begin{aligned} \max_{U, V, e, a, x, y} & \sigma(e) + a[v(e)(x^H + y^H)R^H + (1 - v(e))(x^L + y^L)R^L] + (1 - a)(x^N + y^N)\rho(e) \\ & - \{a[v(e)(U^H + V^H) + (1 - v(e))(U^L + V^L)] + (1 - a)[U^N + v(e)V^{HN} + (1 - v(e))V^{LN}]\} \end{aligned} \tag{24}$$

s.t.

$$U^r \geq 0, \quad V^i, \quad V^{iN} \geq 0 \tag{25}$$

$$(7), (14)–(19), (22)$$

$$U^i + V^i \leq z + R^i; \quad U^N + V^{iN} \leq z + R^i \tag{26}$$

$$0 \leq x^r + y^r \leq 1 \tag{27}$$

$$i = L, H, r = L, H, N.$$

Expression (24) is the expected payoff of the principal, and (25) describes the interim participation constraints of  $A$  and  $I$ , respectively. The incentive-compatibility constraints for truth-telling of  $I$  are given by (14)–(19), while the moral hazard constraints of  $I$  and  $A$  are given respectively by (7) and (22). Expressions (26) and (27) are the resource-allocation constraints.<sup>13</sup>

Solving the above maximization problem, we obtain the following proposition.

*Proposition 3.* Under one-sided revelation, the optimal contract is

$$\begin{aligned} y^H > 0, \quad x^H = 1 - y^H \quad \text{with} \quad U^H \leq y^H(R^H - \rho(\hat{e})), \\ y^N = y^L = 0, \quad x^N = x^L = 1, \\ V^H = z + R^H - U^H, \quad V^{HN} = \Delta, \quad V^L = V^{LN} = 0, \\ U^H = \frac{C'(\hat{a})}{v(\hat{e})}, \quad U^L = U^N = 0. \end{aligned}$$

Productive effort  $\hat{e}$  and auditing effort  $\hat{a}$  are such that

$$\hat{e} = H(\hat{a}),$$

where  $H$  is the implicit function solving

$$\hat{a}v'(\hat{e}) \left( z + R^L - \frac{C'(\hat{a})}{v(\hat{e})} \right) + \rho'(\hat{e}) = 1, \tag{28}$$

<sup>13</sup> Note that the moral hazard constraints and the interim participation constraints imply that the *ex ante* participation constraints of  $I$  and  $A$  are always satisfied at the solution of the maximization program.

and

$$H'(\hat{a}) \left[ \sigma'(\hat{e}) + \rho'(\hat{e}) - \frac{d}{de} \left( \frac{v(\hat{e})}{v'(\hat{e})} \right) \right] - [\hat{a}C''(\hat{a}) + C'(\hat{a})] = 0. \tag{29}$$

To understand the optimal allocation of property rights under one-sided revelation, as described by Proposition 3, recall that in our setting the principal faces two moral hazard problems: one with  $I$ , due to the nonobservability of effort into the productive asset, and one with  $A$ , due to the nonobservability of auditing effort. Since monetary payoffs alone do not induce auditing effort (Proposition 2), the allocation of property rights is *dictated* by the interplay between the adverse-selection and moral hazard problems of  $A$ . First, as suggested in Proposition 2, property rights need to be given to  $A$  when he reports  $R^H$  so as to give him incentive to evaluate the asset *ex ante*. However, property rights in state  $L$  and  $N$  do not help to increase  $a$  and can therefore be left with  $I$ .<sup>14</sup> Then, *once*  $A$  has gathered information and truthfully revealed it, state-contingent monetary payoffs can be used as a compensating differential to discipline  $I$ , who receives

$$V^H = (1 - y^H)R^H + z - t^H$$

$$V^{HN} = \Delta, \quad V^L = V^{LN} = 0.$$

Note the payoff in state  $H$ .  $I$  receives property rights with probability  $(1 - y^H)$  and, as in the case of verifiable auditing, he also receives  $z$  from the principal. The term  $-t^H$  is what  $A$  pays for his property rights and, in light of Proposition 3, is equal to  $y^H R^H - [C'(\hat{a})/v(\hat{e})]$ . The principal uses property rights in the high state to motivate  $A$  to acquire information (Proposition 2), and then uses all the available funds to reward  $I$ . A golden parachute type of reward arises: with positive probability the incumbent is replaced and leaves with a monetary compensation partially financed by the “entrant.”<sup>15</sup>

Further, note the difference in  $I$ 's payoff when  $A$  reveals  $R^H$  between the case described here (where  $V^H = R^H + z - U^H$ ) and the case in Section 5 where auditing is verifiable and  $V^{HH} = R^H + z$ . Auditing comes at the cost of reduced ownership incentives for  $I$ . The payment  $-t^H$  that  $I$  receives from  $A$  is not sufficient to fully compensate him for the loss of property rights (since  $-t^H < y^H R^H$ ). However, as long as  $I$ 's payoff in the high state is greater than  $\Delta$ , monetary transfers suffice to induce  $\hat{e} > e^M$ . This is a direct consequence of Proposition 3 and is stated in the next proposition.

*Proposition 4.* A sufficient condition for  $\hat{e} > e^M$  is that  $z > (1 - v(e^M))\Delta - R^L$ .

Clearly, lack of funds limits the power of the incentive mechanism; but as long as  $(1 - v(e^M))\Delta - R^L$  is not positive (which requires that  $\Delta$  is not too large or that  $v(e^M)$  is large), the condition of Proposition 4 is satisfied and audit can be used to create incentives even when  $z = 0$ .

□ **Two-sided revelation.** In this section we check the robustness of the result that property rights to  $A$  are necessary to generate incentives for reliable auditing. Maintaining our assumption that  $I$  can observe a perfect signal on  $R^i$ , we consider the case where both  $I$  and  $A$  reveal information to the principal. We shall show that it may be desirable for the principal to rely only on the information provided by  $A$ . Thus one-sided revelation (OSR) can be preferred to two-sided revelation (TSR).

One obvious consequence of TSR is to introduce truth-telling conditions for  $I$ ; these are

$$aV^{HH} + (1 - a)V^{HN} \geq (1 - a)V^{LN}$$

$$aV^{LL} + (1 - a)V^{LN} \geq (1 - a)V^{HN}. \tag{30}$$

<sup>14</sup> By setting  $y^N = 0$ , which implies  $y^L = 0$  (from (20)), the principal maximizes the difference in  $I$ 's payoffs ( $V^{HN} - V^{LN}$ ) when  $A$ 's report is uninformative, and  $V^{HN} - V^{LN} = \Delta$ .

<sup>15</sup> On golden parachutes in corporate finance, see, for instance, Harris (1990) and Schnitzer (1995).

It is then immediate that the solution in OSR, as given in Proposition 3, is *not* incentive compatible under TSR whenever  $a < 1$ . Indeed,  $V^{LL} = V^{LN} = 0$  and  $V^{HN} = \Delta$  substituted in (30) yield  $0 \geq (1 - a)\Delta$ , which is violated when  $a < 1$ . However, the fact that the solution to OSR is not feasible with TSR does not imply that OSR dominates TSR.

We turn now to the revelation problem of  $A$ . We show that transmission of  $I$ 's information makes the interim participation constraints of  $A$  tighter and increases the expected rent of  $A$ ; this additional rent might cancel any potential gain from using  $I$ 's information in contracting. The optimal contract under TSR can be feasible under OSR at lower cost, hence the principal can be strictly better off with OSR.

Let  $U^{ir}$  denote the rent of  $A$  when  $I$  reveals  $i$  and  $A$  reveals  $r$ , with  $i = L, H$  and  $r = L, H, N$ . Since the interim participation constraints need to hold at the beginning of period 2, no negative payoffs are implementable when  $I$  and  $A$  disagree on the state ( $R^L$  or  $R^H$ ):  $U^{LH} = U^{HL} = 0$ . Then the relevant deviations are when  $A$  observes the true state to deviate to  $N$  and when he observes nothing to deviate to  $H$  or to  $L$ . Therefore, the incentive-compatibility conditions for  $A$  are

$$U^{HH} \geq U^{HN} \tag{31}$$

$$U^{LL} \geq U^{LN} \tag{32}$$

$$v(\hat{e})U^{HN} + (1 - v(\hat{e}))U^{LN} \geq v(\hat{e})U^{HH} \tag{33}$$

$$v(\hat{e})U^{HN} + (1 - v(\hat{e}))U^{LN} \geq (1 - v(\hat{e}))U^{LL}, \tag{34}$$

and  $A$  chooses  $a$  to solve

$$C^I(a) = v(e)U^{HH} + (1 - v(e))U^{LL} - v(e)U^{HN} - (1 - v(e))U^{LN}. \tag{35}$$

Contrary to OSR, the expected utility of  $A$  when he observes nothing cannot be zero; otherwise, all rents must be equal to zero and there is no audit. It is therefore more costly to implement any given  $a$  with TSR. This illustrates the fact that  $I$ 's revelation makes the interim participation constraints of  $A$  tighter. Under OSR, if  $A$  observes nothing and reveals  $H$ , his expected utility is  $y^H \rho(\hat{e}) + t^H$  and he runs the risk of paying a lot (up to  $y^H R^H$ , since  $U^H \geq 0$ ) for a mediocre asset. Instead, when  $I$ 's information is used in the contract with  $A$ ,  $I$ 's report reveals the true state before  $A$  pays for his property rights. It follows that if  $A$  does not possess information and reveals that the state is  $H$ , he *does not* run this risk of paying too much for the asset ( $U^{LH}$  cannot be negative). Misreporting is safer, and  $A$  will have to be given a positive rent to be induced to reveal that the state is  $N$ , which makes it more expensive to induce him to acquire information (recall that  $A$ 's choice of  $a$  decreases in his rent when he observes nothing). However, in states  $L$  and  $H$ , the incentive-compatibility conditions for  $A$  are weaker than with OSR since, for instance,  $A$  cannot pretend that the state is  $L$  when the true state is  $H$  because he anticipates that  $I$  will reveal that the state is  $H$ .

Now, if we can replicate with OSR the incentive-compatible rents under TSR, OSR must dominate, since lower rents can be given to  $A$ . A sufficient condition for this is that the rent  $U^{HH}$  given to  $A$  under TSR when the state is  $H$  is less than the maximum incentive-compatible rent  $R^H - \rho(e) \equiv (1 - v(e))\Delta$  under OSR (and therefore (23) is not binding).

*Lemma 1.* TSR is dominated by OSR if  $z < v(e^M)\Delta - R^L$ .

This condition requires that the gap  $\Delta$  be large with respect to  $z$ ; the higher the budget  $z$ , the larger the gap  $\Delta$  needs to be for OSR to dominate TSR. Note that the condition in Lemma 1 is consistent with the condition in Proposition 4 only if  $v(e^M) > 1/2$ .

*Proposition 5.* Suppose that  $v(e^M) > 1/2$  and that

$$z \in ((1 - v(e^M))\Delta - R^L, v(e^M)\Delta - R^L).$$

Then OSR dominates TSR and audit creates incentives for the incumbent.

## 7. Conclusion

■ We have considered the problem of a principal who needs to motivate an auditor to acquire and truthfully reveal information; that information in turn is valuable for providing incentives to another agent. In this setting, we have obtained two results. First, when the agent and the auditor have interim participation constraints, the principal may strictly prefer to ignore the information of the agent and rely only on the auditor's information. Second, property rights are an effective device to induce information acquisition and truthful revelation by the auditor. In particular, sales of assets at some posted price may be the only way to generate information that disciplines agents.

When the auditors themselves are subject to a moral hazard problem, it is not likely that the communication between the principal and the auditor will yield information that can be used for contracting. If auditing is to be effective, the auditors must directly value the information they obtain. The only way to achieve this is by assigning rights on claims on the future value of the asset to the auditors. Hence, the market for property rights serves two functions. First, it allocates valuable assets to agents willing to make productive use of them. Second, it works as an information-collection device that reveals the value of the asset. As we have indicated in the Introduction, a simple modification of licensing auctions, e.g., along the lines implemented by the World Bank in Argentina, could implement such a mechanism in regulatory settings.

Three assumptions are essential for our results: (i) limited budget of the principal, (ii) lack of certification of the outcome of audit, and (iii) interim participation constraints of the agents. These assumptions seem particularly relevant for regulatory settings in countries with less-developed financial markets and institutions. However, as we have witnessed in recent cases in the United States, they might be relevant even in our economies. Of course, this article is essentially a theoretical contribution. It would be interesting in future work to consider more detailed regulatory settings and dynamics. Let us end by discussing two limitations to our analysis.

We have restricted our attention to a two-period model. An extension of our analysis to a longer horizon introduces the complication that the incentives for the entrant to exert effort (if he obtains the right to use the asset) are a function of the realized outcome. Auditing serves now two roles: a "backward" role of monitoring the past performance of the incumbent and a "forward" role of predicting the future effect of effort levels.

Clearly, as in all settings that rely on external auditing to monitor the agent, there may be scope for collusion between the auditor and the agent. However, collusion is not always a problem: its lack of enforceability, the communication costs it involves, and the threat of being caught and punished can all be effective deterring factors. In this respect, our article should be viewed as a first step toward a better understanding of the value of auditing in worlds where agents' performance is unverifiable and the auditing effort and outcome are unobservable. Whether the possibility of collusion could jeopardize the use of sales as a device to evaluate the work of agents is an issue left to future research.

## Appendix

■ Proofs of Propositions 1–4, Corollary 1, and Lemma 1 follow.

*Proof of Proposition 1.* Suppose that the principal asks  $I$  to reveal information about  $R^i$ , and let the contract be  $(x^{ir}, s^{ir})$ , with associated utility  $V^{ir} = x^{ir}R^i + s^{ir}$  when  $I$  observes and reveals signal  $i = L, H$  and the auditing outcome is  $r \in \{L, H, N\}$ . We show that the optimal contract is characterized as follows:

$$\begin{aligned} x^{LL} &= x^{HH} = x^{HN} = x^{LN} = 1 \\ s^{LL} &= -R^L, s^{HH} = z, s^{LN} = s^{HN} = -R^L, \end{aligned}$$

which yields  $V^{LL} = V^{LN} = 0$ ,  $V^{HH} = z + R^H$ ,  $V^{HN} = \Delta$ , (12), and (13) and proves that  $I$ 's information is not used in the optimal contract. To this purpose let us rewrite (10) and (11) as follows:

$$\begin{aligned} aV^{HH} + (1-a)V^{HN} &\geq (1-a)(V^{LN} + x^{LN}\Delta) && \text{(IC - H)} \\ aV^{LL} + (1-a)V^{LN} &\geq (1-a)(V^{HN} - x^{HN}\Delta). && \text{(IC - L)} \end{aligned}$$

The proof is then established by a series of claims.

*Claim 1.*  $V^{HN} \leq x^{HN} \Delta$ .

Suppose not. Then  $V^{HN} > x^{HN} \Delta$  implies that (IC-L) is binding, otherwise the principal could reduce the left-hand side of (IC-L), still satisfy (IC-H) and (IC-L), and increase  $e$  (from 7). When (IC-L) is binding, (7) becomes

$$aV^{HH} + (1 - a)x^{HN} \Delta = \frac{1}{v'(e)}, \tag{A1}$$

and we observe that  $V^{HN}$  does not affect the choice of  $e$ .

*Claim 2.*  $V^{HH} = z + R^H, x^{HH} = 1$ .

Note that auditing can be optimal only if  $V^{HH} > \Delta$ , otherwise  $\hat{e} < e^M$  (from Claim 1 and expression (2)). If  $\Delta < V^{HH} < z + R^H$ , the principal can increase  $V^{HH}$  and reduce  $a$  so as to leave the expected rent of  $I$  and his choice of  $e$  unchanged (from (6) and (A1)) and save on the transfer  $C(a^*)$  that needs to be paid to  $A$  for auditing. Therefore,  $V^{HH} = z + R^H$  with  $x^{HH} = 1$  and  $s^{HH} = z$  (alternatively, the principal could sell the asset to another agent at a price equal to  $R^H$  and transfer this money plus  $z$  to  $I$ ; this possibility will be ruled out throughout, without loss of generality).

*Claim 3.*  $V^{HN} = \Delta, x^{HN} = 1$ .

Suppose  $V^{HN} < \Delta$ . Then the principal can increase  $V^{HN}$  and reduce  $a$  so as to leave the expected rent of  $I$  (expression(6)) unchanged (since  $V^{HH} > V^{HN}$ , from Claims 1 and 2) and save on  $C(a^*)$ . Therefore,  $V^{HN} = \Delta$ , with  $x^{HN} = 1$  and  $s^{HN} = -R^L$ .

*Claim 4.*  $V^{LL} = V^{LN} = 0, x^{LL} = x^{LN} = 1$ .

Since (IC-L) is binding (from reasoning in Claim 1), Claim 3 also implies that  $V^{LL} = V^{LN} = 0$ , with  $x^{LL} = x^{LN} = 1$  and  $s^{LL} = s^{LN} = -R^L$ .

In light of Claims (1)–(4),  $I$  chooses effort to maximize

$$v(e)[a(z + R^H) + (1 - a)\Delta] - e \equiv v(e)[a(z + R^L) + \Delta] - e, \tag{A2}$$

which yields expression (12), and due to the concavity of the expected rent with respect to  $e$ , the *ex ante* participation constraint of  $I$  is satisfied (i.e., (6) is positive). Expression (13) follows by differentiating the principal’s payoff with respect to  $a$ , taking into account that the *ex post* rent of  $I$  is given by  $v(e^*)/v'(e^*)$  in light of (A2) and (12) and that  $A$  receives a monetary compensation equal to  $C(a^*)$ . Since  $C'(a^*) > 0, e^* < e^{FB}$ ; and from (A2),  $e^* > e^M$  even at  $z = 0$ . *Q.E.D.*

*Proof of Proposition 2.*

- (i) From (14)–(19) and (20), when  $y^H = 0$ , truth-telling requires  $U^H = U^N = U^L$ , but then from (22)  $a = 0$ . Now suppose that  $y^H > 0, y^L = y^N = 0, 0 < U^H \leq y^H(R^H - \rho(\hat{e}))$ , and  $U^L = U^N = 0$ . Then (14)–(19) are satisfied, and, due to the concavity of the expected rent with respect to  $a$ , the *ex ante* participation constraint of  $A$  is satisfied (i.e., (21) is positive). Further, from (22),  $a > 0$ .
- (ii) First, to induce information acquisition  $U^H$  needs to be positive; otherwise, from (14)–(19), which imply  $U^H \geq U^N \geq U^L, a$  would be zero. Therefore,  $-t^H < y^H R^H$ . Second, note from (22) that an increase in  $U^N$  depresses incentives, and so does an increase in  $U^L$ , since  $U^N$  needs to rise proportionally (from (19)). Then, suppose that  $U^H > y^H(R^H - \rho(\hat{e}))$ . From (18),  $U^N$  needs to be positive and at least equal to  $U^H - y^H(R^H - \rho(\hat{e}))$ , but from (22),  $a$  can be increased by reducing  $U^H$ , still satisfying (14)–(19). Therefore,  $U^H \leq y^H(R^H - \rho(\hat{e}))$ , which implies  $-t^H \geq y^H \rho(\hat{e})$ . *Q.E.D.*

*Proof of Corollary 1.* From Proposition 2,  $U^H \leq y^H(R^H - \rho(\hat{e}))$ , hence at most  $U^H = R^H - \rho(\hat{e})$ . Then, expression (23) follows by noticing that  $R^H - \rho(\hat{e}) \equiv (1 - v(\hat{e}))\Delta$ . *Q.E.D.*

*Proof of Proposition 3.* The proof is established by a series of claims.

*Claim 5.*  $U^L = 0$ .

From (19) and (22), an increase in  $U^L$  reduces incentives to acquire information, since  $U^N$  needs to rise proportionally. Since  $y^H(R^H - \rho(\hat{e})) \geq U^H \geq U^N \geq U^L$  (from Proposition 2(ii) and constraints (14)–(19)),  $U^L$  can be reduced to zero without violating any constraints.

*Claim 6.*  $U^N = y^L(\rho(\hat{e}) - R^L), y^L = 0$ .

Suppose that  $U^N > y^L(\rho(\hat{e}) - R^L)$  and let  $\hat{U}^N = U^N - \delta U$  and  $\hat{U}^H = U^H - \delta U$ . Then (14)–(19) continue to hold and (22) becomes

$$v(e)(U^H - \delta U) - (U^N - \delta U) = C'(a),$$



and since  $\delta U(1 - v(e)) > 0$ ,  $a$  increases. Thus, the principal can decrease  $V^H$  without changing incentives for  $e$ . A similar argument shows that  $y^L = 0$ .

*Claim 7.*  $U^H = C'(\hat{a})/v(\hat{e}) \leq C'(a_{\max}(\hat{e}))/v(\hat{e})$ .

This follows from Claims 5 and 6 and expressions (22) and (23).

*Claim 8.*  $y^N = 0, x^N = 1$ .

Note that  $y^N$  does not affect the moral hazard and adverse-selection problems of the auditor, while, from (7),  $e$  is increasing in  $V^{HN} - V^{LN} = x^N \Delta$ .

*Claim 9.*  $V^{LN} = V^L = 0, x^L = 1$ .

If  $V^{LN} > 0$ ,  $e$  can be increased by reducing  $V^{LN}$ . The same holds with  $V^L$  and  $x^L = 1$  and  $s^L = s^N = -R^L$ .

*Claim 10.*  $V^{HN} = \Delta$ .

$V^{HN} > \Delta$ , in the absence of revelation by  $I$ , can be obtained only by increasing  $V^{LN}$  (since  $V^{HN} \equiv x^N R^H + s^N$  and  $V^{LN} \equiv x^N R^L + s^N$ ), which was proved never to be optimal (Claim 9). Therefore,  $V^{HN} \leq \Delta$  and  $V^{HH}$  must be greater than  $\Delta$ , otherwise  $\hat{e} \leq e^M$ . Then, if  $V^{HN} < \Delta$ , the principal can increase  $V^{HN}$  and reduce  $a$  so that the expected rent of  $I$  and his choice of  $e$  remain the same (from 6 and 7) while saving on  $U^H$ .

*Claim 11.*  $U^H + V^H = z + R^H, x^H + y^H = 1$ .

Suppose that  $U^H + V^H < z + R^H$ . Then the principal can increase  $V^H$ , decrease  $a$  (by reducing  $U^H$ ), and keep the expected rent of  $I$  and  $e$  unchanged (from 6 and 7). This, in light of Claim 7, implies that  $t^H = -y^H R^H + [C'(\hat{a})/v(\hat{e})]$ , and  $I$  obtains  $(1 - y^H)R^H + z - t^H = R^H + z - U^H$ , where the choice of  $y^H$  is irrelevant provided that  $C'(\hat{a})/v(\hat{e}) \leq y^H(R^H - \rho(\hat{e}))$  (from the proof of Proposition 2(ii)). It follows that  $x^H + y^H = 1$ .

From Claims 5 to 11,  $I$  chooses effort so as to maximize

$$v(e) \left[ \hat{a} \left( z + R^L - \frac{C'(\hat{a})}{v(\hat{e})} \right) + \Delta \right] - e, \tag{A3}$$

which yields the equilibrium condition (28). Note that the left-hand side is an increasing concave function of  $\hat{e}$ . Hence, for each  $\hat{a}$  there exists a unique  $\hat{e}$  satisfying (28). At the optimal contract, the moral hazard problem of  $A$  is solved, since the *ex ante* rent of  $A$  is  $aC'(\hat{a}) - C(a)$ , whose unique maximum is  $a = \hat{a}$ , and the moral hazard problem of  $I$  is solved when  $\hat{e}$  solves (28). Expression (29) follows by differentiating the principal's payoff with respect to  $a$ . *Q.E.D.*

*Proof of Proposition 4.* Since  $\hat{e}$  solves  $v'(\hat{e})[a(z + R^L - U^H) + \Delta] = 1$ ,  $\hat{e} > e^M$  only if the term in parentheses is positive. Since  $U^H \leq (1 - v(\hat{e}))\Delta$ , then  $z + R^L - U^H \geq z + R^L - (1 - v(\hat{e}))\Delta > z + R^L - (1 - v(e^M))\Delta$ , where the last inequality presumes  $\hat{e} > e^M$ . Hence if  $z + R^L - (1 - v(e^M))\Delta \geq 0$ ,  $\hat{e} > e^M$  as long as  $a$  is positive. *Q.E.D.*

*Proof of Lemma 1.* Consider the incentive-compatibility constraints for TSR. Observe that if  $U^{LL} = 0$ , (32) implies  $U^{LN} = 0$ , and (31) and (33) imply  $U^{HH} = U^{HN}$ . But then, in (35),  $C'(a) = 0$  and there is no audit. Suppose that  $U^{LL} > 0$  and  $v(e)U^{HH} > (1 - v(e))U^{LL}$ . By decreasing  $U^{HN}$  and  $U^{LN}$ , (33) can be made binding without violating the other constraints. Hence,  $v(\hat{e})U^{HN} + (1 - v(\hat{e}))U^{LN} = v(\hat{e})U^{HH} > (1 - v(\hat{e}))U^{LL}$ , and by (35),  $C'(a) = (1 - v(\hat{e}))U^{LL}$ . Since  $U^{LL} \geq U^{LN}$ , constraint (34) is violated if  $U^{HN} = 0$ . Hence,  $U^{HN}$  and  $U^{HH}$  can be decreased by the same amount  $\delta$  up to the point where  $v(e)(U^{HH} - \delta) = (1 - v(e))U^{LL}$ ; note that (31) and (33) are preserved, since both sides decrease by the same amount  $v(e)\delta$ . The same reasoning can be made if  $(1 - v(e))U^{LL} > v(e)U^{HH}$ . It follows that at an optimum with TSR, both (33) and (34) bind and  $C'(a) = v(e)U^{HH}$ .

Suppose that  $U^{HH} \leq R^H - \rho(e) \equiv (1 - v(e))\Delta$ . Then, defining  $\hat{U}^H = U^{HH}$ ,  $\hat{U}^N = \hat{U}^L = 0$ , we observe that  $(\hat{U}^L, \hat{U}^H, \hat{U}^N)$  satisfy the incentive-compatibility conditions for OSR and, moreover, that the total rents are lower. Hence,  $(e, a)$  is implemented at lower cost by OSR.

Suppose now that  $U^{HH} > (1 - v(e))\Delta$ . Since, by feasibility,  $U^{LL} \leq z + R^L$ , there is an upper bound for  $U^{HH}$ :

$$U^{HH} = \frac{1 - v(e)}{v(e)} U^{LL} \leq \frac{1 - v(e)}{v(e)} (z + R^L).$$

These bounds are consistent only if

$$\frac{1 - v(e)}{v(e)} (z + R^L) > (1 - v(e))\Delta \iff z \geq v(e)\Delta - R^L \iff z \geq v(e^M)\Delta - R^L,$$

where the last inequality presumes  $e \geq e^M$ . Hence, whenever  $z < v(e^M)\Delta - R^L$ , we cannot have  $U^{HH} > (1 - v(e))\Delta$  in the optimum of TSR unless  $e < e^M$ ; but then it is best not to use auditing with TSR, and OSR dominates. *Q.E.D.*

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