Imperfect Auditing, Appeals, and Limited Liability

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June 18, 2008

Abstract

We examine the effect of an imperfect audit and a subsequent appeals process in a standard adverse selection problem when legal or institutional restrictions impose an upper bound on penalties. We show that the imperfect audit always reduces the agent's information rent and enhances efficiency despite the limited liability. A subsequent appeals process, which allows the agent to challenge an unfavorable finding by the audit, is never optimal when it is costless. However, when the appeals process is costly, it can be optimal even if it is less accurate than the audit. Moreover, social welfare can increase as the cost of the appeals process increases.

Keywords: Auditing; Appeals; Limited Liability

JEL classification: D8, L5

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1 Introduction

In standard adverse-selection problems, such as Laffont and Tirole (1986), a principal (e.g., a regulator) contracts with a risk-neutral agent (e.g., a firm) who is privately informed of its inherent cost of production. The optimal contract for the principal eliminates all rent for a high-cost agent and affords positive rent to a low-cost agent, and it distorts the production from their efficient levels.

In many circumstances, information that is correlated with the agent's private information can be made public ex post, for example, by an imperfect audit. If the principal can impose unlimited penalty on the agent whenever the ex post information is inconsistent with the agent's earlier revelation of its private information, Baron and Besanko (1984) and Riordan and Sappington (1988) among others show that all of the agent's rent can be eliminated and efficient production can be achieved.

However, in practice, legal or institutional restrictions often impose upper bounds on the size of penalties. For example, administrative laws often specify the maximum punishments for violations, and bankruptcy clauses effectively restrict the size of penalties to be no more than one's asset.

Moreover, with imperfect ex post information, an agent who has truthfully revealed its private information could be penalized by mistake. In practice, an agent who disagrees with the punishment might be able to challenge the decision. In fact, the appeals process is widely employed by organizations, such as administrative agencies, regulatory authorities, and firms, as a means of error correction.

This paper examines the effect of imperfect auditing and a subsequent appeals process in a principal-agent relationship when legal or institutional restrictions impose an upper bound on penalties. We show that the imperfect auditing always reduces the agent's information rent and enhances efficiency despite the limited liability. However, when the audit is sufficiently inaccurate and the penalty is restricted to be sufficiently small, the principal can no longer eliminate all of the agent's rent or achieve efficient production.

The subsequent appeals process, which allows the agent to challenge an unfavorable finding by the audit, enhances efficiency only if it is more accurate than the audit when it is costless. However, we show that it is optimal for the principal to eliminate the appeals process and simply replace the audit with the more accurate investigation, if a more accurate investigation is available. Consequently, implementing the appeals process is never optimal when it is costless.

However, when the appeals process is costly, implementing the appeals process can be optimal even if it is less accurate than the audit. This is because the appellant's share of the cost can be viewed as a forfeitable bond that must be posted in order to appeal. The forfeitable bond helps separate different types of agents through the appeals process. We also find that it is optimal for the principal to impose all the cost of appeals on the appellant and the expected social welfare can increase as the cost of the appeals process increases.

Our research relates to several studies on limited liability. Lawarrée and Van Audenrode (1992) examine the effect of limited liability in a similar setting as ours. They show that an imperfect audit, which could mistakenly penalize an honest agent, is never profitable for the principal if limited liability requires that an honest agent cannot receive a negative rent. In contrast, we show that an imperfect audit is always valuable for the principal when limited liability is in the form of an upper bound on penalties. Sappington (1983) examines the optimal strategy of the principal when limits are imposed on the maximum penalty. While Sappington considers a case with ex ante symmetric information, we analyze a case with ex ante asymmetric information. Moreover, we consider the effect of imperfect auditing and the appeals process.

Our research also relates to the literature on the appeals process. Shavell (1995) studies the role of the appeals process as a means of error correction in judicial settings where either litigant disappointed with a first-order decision can seek reconsideration before a higher tribunal. In contrast, we study the role of the appeals process in a principal-agent setting where an agent can seek the principal's reconsideration of her initial decision. Dai (2008) examines the dual role of the appeals process in enhancing fairness and inducing performance in principal-agent relationships in the presence of imperfect performance evaluation. Spitzer and Talley (2000) analyze a hierarchical system of judicial auditing where an appeals court is concerned with not only imprecision but also ideological bias of a trial court.

The rest of the paper is organized as follows. Section 2 describes the central elements of the model. Section 3 demonstrates the effect of imperfect auditing in the presence of limited liability. Section 4 analyzes the effect of a subsequent appeals process. Section 5 summarizes the main findings and concludes the paper with future research directions.

2 Elements of the model

As in Laffont and Tirole (1986) (L&T henceforth), a utilitarian regulator (the principal) wishes to realize a public project with social value S. A single risk-neutral firm (the agent) can realize the project, at a total cost $c = \beta - e$, where β is the firm's cost parameter for the project and e is its effort. The regulator cannot observe either the firm's cost parameter or its effort. However, it is common knowledge that the cost parameter belongs to the two point support $\{\underline{\beta}, \overline{\beta}\}$ with $\overline{\beta} > \underline{\beta}$ and $\Pr(\beta = \underline{\beta}) = v$ (therefore $\Pr(\beta = \overline{\beta}) = 1 - v$). The firm's cost of effort is $\psi(e)$ with $\psi'(e) > 0$, $\psi''(e) > 0$, and $\psi'''(e) > 0$. The total production cost is observable to the regulator and is reimbursed to the firm by the regulator. The firm is also compensated by a net monetary transfer t in addition to the reimbursement of cost.

The firm's profit function is $\pi \equiv t - \psi(e)$.

The regulator offers a contract specifying a transfer-cost pair for each type of firm, namely $\{t(\underline{\beta}), c(\underline{\beta})\}$ for $\beta = \underline{\beta}$ and $\{t(\overline{\beta}), c(\overline{\beta})\}$ for $\beta = \overline{\beta}$. For notation simplicity, let $\underline{t} \equiv t(\underline{\beta})$, $\underline{c} \equiv c(\underline{\beta})$, $\underline{\pi} \equiv t(\underline{\beta}) - \psi(\underline{\beta} - \underline{C})$, $\bar{t} \equiv t(\overline{\beta})$, $\bar{c} \equiv c(\overline{\beta})$, and $\overline{\pi} \equiv t(\overline{\beta}) - \psi(\overline{\beta} - \overline{C})$.

We assume that the regulator can raise public fund only through a distortionary mechanism, and $\lambda > 0$ denotes the shadow cost of public fund. Then the expected consumer surplus is $S - (1+\lambda)\{v(\underline{t} + \underline{c}) + (1-v)[\bar{t} + \bar{c}]\}$. The expected social welfare of the project, W, is the aggregation of the expected consumer surplus and the expected profit of the firm. Therefore,

$$W = S - (1+\lambda)[v(\underline{t} + \underline{c}) + (1-v)(\bar{t} + \bar{c})] + [v\underline{\pi} + (1-v)\overline{\pi}] \tag{1}$$

$$= S - v[\lambda\underline{t} + (1+\lambda)\underline{c} + \psi(\underline{\beta} - \underline{c})] - (1-v)[\lambda\underline{t} + (1+\lambda)\bar{c} + \psi(\overline{\beta} - \bar{c})].$$

Suppose that the regulator can observe the firm's cost parameter at the time of contracting, then the optimal contract would be characterized by the following equations:

$$\psi'(\underline{\beta} - \underline{c}^*) = \psi'(\overline{\beta} - \bar{c}^*) = 1; \tag{2}$$

$$\underline{t} = \psi(\underline{\beta} - \underline{c}^*); \text{ and} \tag{3}$$

$$\bar{t} = \psi'(\overline{\beta} - \bar{c}^*). \tag{4}$$

In words, under the optimal contract, both types of firms would deliver the efficient level of effort and receive zero rent. For later use, we define $e^* \equiv \underline{\beta} - \underline{c}^* = \overline{\beta} - \bar{c}^*$, i.e., e^* is the efficient level of effort for both types of firms.

3 Imperfect auditing

After the completion of the project, the regulator audits the firm's cost parameter with probability $0 \leqslant \delta \leqslant 1$ when the firm has claimed to have high cost parameter. The audit correctly reveals the firm's cost parameter with a probability r, where $1 > r > 1/2$. However, with probability $1-r$, the regulator mistakenly accuses an actual high-cost firm as a cheating low-cost firm. If the firm is accused of cheating, it is punished with a penalty p. Institutional or legal restrictions impose an upper bound $L > 0$ on the size of penalty, i.e., $p \leqslant L$. For simplicity, the audit is assumed to be costless.

The timing of the model is as follows: 1) The regulator offers a contract specifying a transfer-cost pair for each type of firm. 2) The firm announces its cost parameter β. 3) The firm delivers effort and the total cost is observed. 4) exchange takes place according to the contract. 5) The regulator performs an audit with probability δ if the firm has reported $\overline{\beta}$, and imposes a penalty p on the firm if it is found to have exaggerated its cost parameter. We abstract from the appeals process until section 4.

With imperfect auditing, the expected social welfare of the project becomes

$$\begin{aligned} W &= S - v[\lambda \underline{t} + (1+\lambda)\underline{c} + \psi(\underline{\beta} - \underline{c})] \\ &\quad -(1-v)[\lambda(\overline{t} - \delta(1-r)p) + (1+\lambda)\overline{c} + \psi(\overline{\beta} - \overline{c})]. \end{aligned} \tag{5}$$

We assume the social value of the project is so large that the regulator always wishes to realize the project. The firm will participate in a contract if and only if its expected profit from the contract is nonnegative. Therefore, the regulatory policy must satisfy the following individual rationality conditions:

$$\overline{\pi} = \overline{t} - \delta(1-r)p - \psi(\overline{\beta} - \overline{c}) \geqslant 0, \text{ and} \tag{6}$$

$$\underline{\pi} = \underline{t} - \psi(\underline{\beta} - \underline{c}) \geqslant 0. \tag{7}$$

To ensure that the firm truthfully reveals its cost parameter for the project, the transfer-cost pair designed for a type $\underline{\beta}$ (respectively a type $\overline{\beta}$) firm must be the one preferred by a type $\underline{\beta}$ (respectively a type $\overline{\beta}$) firm. Therefore, the regulatory policy must also satisfy the following incentive compatibility conditions:

$$\overline{t} - \delta(1-r)p - \psi(\overline{\beta} - \overline{c}) \geqslant \underline{t} - \psi(\overline{\beta} - \underline{c}), \text{ and} \tag{8}$$

$$\underline{t} - \psi(\underline{\beta} - \underline{c}) \geqslant \overline{t} - \psi(\underline{\beta} - \overline{c}) - \delta r p. \tag{9}$$

Finally, the regulatory policy must comply with the restriction on the size of penalty:

$$p \leqslant L. \tag{10}$$

The regulator's optimization problem is choosing $\{\underline{c}, \overline{c}, \underline{t}, \overline{t}, \delta, p\}$ to maximize the expected social welfare, W, subject to conditions (6), (7), (8), (9) and (10).

The optimal regulatory policy depends on the accuracy of the audit and the restriction on the size of penalty. Define $\Delta\psi(e) \equiv \psi(e) - \psi(e - \Delta\beta)$ where $\Delta\beta \equiv \overline{\beta} - \underline{\beta}$. (Since $\psi''(e) > 0$ and $\psi'''(e) > 0$, it can be readily shown that $\Delta\psi' > 0$ and $\Delta\psi'' > 0$.) When $L > \Delta\psi(e^*)/(2r-1)$ or $r > 1/2 + \Delta\psi(e^*)/2L$, the regulator can impose a sufficiently large penalty on an accused firm or the audit is sufficiently accurate. In this case, the regulator can implement the efficient contract $\{\underline{c} = \underline{c}^*, \overline{c} = \overline{c}^*, \underline{t} = \psi(\underline{\beta} - \underline{c}^*), \overline{t} = \psi(\overline{\beta} - \overline{c}^*)\}$ by auditing with some probability $0 < \delta < 1$. Under the contract, both types of firms deliver the efficient level of effort and receive no rent for their private information on cost parameters.

However, when $L < \Delta\psi(e^*)/(2r-1)$ or $r > 1/2 + \Delta\psi(e^*)/2L$, the regulator can no longer implement the above efficient contract. In this case, the regulator always performs the audit ($\delta = 1$) as long as she can impose any positive penalty on an accused firm. Under the optimal auditing policy, a low-cost firm delivers the efficient level of effort but a high-cost firm delivers a less than efficient level of effort. Let $\overline{e}^{**}(< e^*)$ denote the optimal level of effort for a high-cost firm in the absence of auditing (as in L&T). Under the optimal auditing policy, both types of firms receive no rent and a high-cost firm delivers a level of effort between e^{**} and e^* when $\Delta\psi(\overline{e}^{**})/(2r-1) < L < \Delta\psi(\overline{e}^{*})/(2r-1)$. When $L < \Delta\psi(\overline{e}^{**})/(2r-1)$, a high-cost firm delivers the effort $\overline{e}^{**}$ and receives no rent but a low-cost firm receives a positive rent (which is smaller than that in L&T).

We summarize the above properties of the optimal contract under imperfect auditing in Proposition 1.

Proposition 1 *The regulator always audits with some positive probability, and the efficient outcomes can be achieved when $L \geqslant \Delta\psi(e^*)/(2r-1)$. When $L < \Delta\psi(e^*)/(2r-1)$, the regulator audits with certainty ($\delta = 1$), and a low-cost firm delivers the efficient level of effort but a high-cost firm delivers less than the efficient level of effort; the auditing mitigates a low-cost firm's information rent and enhances efficiency.*

Proof. See Appendix A. ■

The intuition behind Proposition 1 is the following. The auditing penalizes a cheating low-cost firm with probability r and mistakenly punishes a high-cost firm with probability $1-r$. Since a high-cost firm receives no rent in the optimal contract, the regulator must fully compensate the high-cost firm for the expected mistaken punishment in order to induce its participation. Therefore, the audit reduces the low-cost firm's expected rent of mimicking a high-cost firm by $(2r-1)p$ if the regulator can impose a positive penalty, p, on an accused firm. When the penalty is sufficiently large, the existence of auditing can fully prevent a low-cost firm from mimicking a high-cost firm and the regulator can achieve the efficient outcome.

However, when the regulator cannot impose a large penalty on an accused firm (i.e., $L < \Delta\psi(e^*)/(2r-1)$), the auditing alone can no longer fully deter a low-cost firm from exaggerating its cost parameter. The regulator has to distort the effort level of a high-cost firm downwards to mitigate a low-cost firm's incentive to mimic a high-cost one. Moreover, the effort distortion must be increased accordingly as the size of the penalty decreases. When the size of penalty is very limited (i.e., $L < \Delta\psi(\overline{e}^{**})/(2r-1)$), it is no longer optimal for the regulator to further distort the effort level of a high-cost firm. Then the regulator optimally affords a low-cost firm a positive rent to induce truthful information revelation.

To best demonstrate the effect of the appeals process, the rest of the paper focuses on situations where the limits on liability are constraining. In other words, Assumption 1 is made for the rest of the paper:

Assumption 1 $L < \Delta\psi(e^*)/(2r-1)$.

Since Proposition 1 shows that the regulator audits with certainty (i.e., $\delta = 1$) when $L < \Delta\psi(e^*)/(2r-1)$, we consider $\delta = 1$ for the rest of our analysis.

4 An Appeals Process

In this section we consider an appeals process subsequent to the auditing. Suppose with probability θ the firm can lodge an appeal when it is accused of cheating by the audit. Upon the firm's appeal, the regulator launches an investigation into the firm's cost parameter. The investigation correctly reveals the firm's cost parameter with probability $a > 1/2$. The regulator removes the original penalty if the investigation reveals that the firm is innocent, but upholds the original penalty if the investigation confirms the original accusation. Let

Z denote the total cost of the appeals process and η denote the regulator's share of the cost.

In the presence of the appeals process, the expected social welfare becomes

$$\begin{aligned} W \equiv\ & S - v\{\lambda \underline{t} + (1+\lambda)\underline{c} + \psi(\underline{\beta} - \underline{c})\} - (1+\lambda)(1-v)(1-r)\theta\eta Z \\ & -(1-v)\{\lambda[\overline{t} - (1-r)((1-\theta a)p + \theta(1-\eta)Z)] + (1+\lambda)\overline{c} + \psi(\overline{\beta} - \overline{c})\}. \quad (11) \end{aligned}$$

The individual rationality conditions which guarantee the participation of both types of firms become

$$\overline{\pi} = \overline{t} - (1-r)[(1-\theta a)p + \theta(1-\eta)Z] - \psi(\overline{\beta} - \overline{c}) \geqslant 0, \quad (12)$$

$$\text{and } \underline{\pi} = \underline{t} - \psi(\underline{\beta} - \underline{c}) \geqslant 0. \quad (13)$$

An innocent high-cost firm will appeal the penalty only if the expected benefit ap (the penalty is removed with probability a) exceeds its cost of appealing $(1-\eta)Z$. Therefore, the appeals process must satisfy the following condition in order to induce an innocent high-cost firm to appeal:

$$ap \geqslant (1-\eta)Z \quad (14)$$

The following incentive compatibility conditions induce both types of firms to truthfully announce their cost parameters:

$$\overline{t} - (1-r)[(1-\theta a)p + \theta(1-\eta)Z] - \psi(\overline{\beta} - \overline{c}) \geqslant \underline{t} - \psi(\overline{\beta} - \underline{c}), \text{ and} \quad (15)$$

$$\underline{t} - \psi(\underline{\beta} - \underline{c}) \geqslant \overline{t} - \psi(\underline{\beta} - \overline{c}) - r[p - \theta \max\{0, (1-a)p - (1-\eta)Z\}]. \quad (16)$$

Notice that a cheating low-cost firm will appeal only if the expected benefit $(1-a)p$

(the penalty is removed with probability $1-a$) exceeds its cost of appealing $(1-\eta)Z$.

The regulator's optimization problem is choosing $\{\underline{c}, \overline{c}, \underline{t}, \overline{t}, \theta, p\}$ to maximize the expected social welfare, W, subject to conditions (10), (12), (13), (14), (15), and (16).

4.1 A costless appeals process

As a benchmark, we first consider an appeals process involving no cost (i.e., $Z = 0$). In this case, as we demonstrate below, the effect of the appeals process depends solely on its accuracy relative to the accuracy of the auditing.

The first-order conditions regarding $\underline{c}$, $\overline{c}$, $\underline{t}$, and $\overline{t}$ are given by

$$\pounds_{\overline{c}} = (1-v)[\psi'(\overline{\beta}-\overline{c}) - (1+\lambda)] + \mu_1\psi'(\overline{\beta}-\overline{c}) - \mu_3\psi'(\underline{\beta}-\overline{c}) = 0, \tag{17}$$

$$\pounds_{\underline{c}} = v[\psi'(\underline{\beta}-\underline{c}) - (1+\lambda)] + \mu_2\psi'(\underline{\beta}-\underline{c}) + \mu_3\psi'(\underline{\beta}-\underline{c}) = 0, \tag{18}$$

$$\pounds_{\overline{t}} = -(1-v)\lambda + \mu_1 - \mu_3 = 0, \tag{19}$$

$$\pounds_{\underline{t}} = -v\lambda + \mu_2 + \mu_3 = 0, \text{ and} \tag{20}$$

where μ_1, μ_2, and μ_3 are the Lagrange multipliers associated with constraints (12), (13), and (16), respectively.* Since equation (15) suggests $\mu_1 = (1-v)\lambda + \mu_3$, the first-derivative regarding θ is

$$\begin{aligned} \pounds_{\theta} &= [\mu_1 - (1-v)\lambda](1-r)ap - \mu_3 r(1-a)p \\ &= \mu_3(a-r)p. \end{aligned} \tag{21}$$

The optimal appeals process depends on the accuracy of the appeals process. When

*It can be verified that the solution of the optimization problem under conditions (10), (6), (7), and (8) satisfies condition (9).

$a \geqslant r + [\Delta\psi(e^*) - (2r-1)L]/L = (1-r) + \Delta\psi(e^*)/L$, (i.e., the appeals process is sufficiently more accurate than the audit,) the regulator can enforce the efficient contract $\{\underline{c} = \underline{c}^*, \overline{c} = \overline{c}^*, \underline{t} = \psi(\underline{\beta} - \underline{c}^*), \overline{t} = \psi(\overline{\beta} - \overline{c}^*)\}$ by implementing the appeals process with some probability $0 < \theta < 1$. Notice that $[\Delta\psi(e^*) - (2r-1)L]/L > 0$ under Assumption 1.

When $a < (1-r) + \Delta\psi(e^*)/L$, however, constraint (16) becomes binding ($\mu_3 > 0$) and the regulator can no longer implement the efficient contract as a result. Then equation (21) indicates that $\pounds_\theta \gtreqless 0$ if $a \gtreqless r$. In words, the regulator implements the appeals process with certainty ($\theta = 1$) if it is more accurate than the audit, but eliminates the appeals process completely if otherwise. In this case, a low-cost firm delivers the efficient level of effort but a high-cost firm delivers less than the efficient level of effort.

The above findings suggest that the regulator implements the appeals process with positive probability only if it is more accurate than the audit. We state this property of the appeals process in Proposition 2.

Proposition 2 *The costless appeals process is valuable only if it is more accurate than the audit.*

The effect of the appeals process is two-fold. On one hand it may correctly remove a mistaken punishment on a high-cost firm; on the other hand, it may mistakenly remove a correct penalty on a cheating low-cost firm. The former effect in expectation reduces the mistaken punishment on a high-cost firm by $(1-r)ap$. However, the latter effect reduces a cheating low-cost firm's expected penalty by $r(1-a)p$. When the appeals process is less accurate than the audit (i.e., $a < r$), $r(1-a)p > (1-r)ap$ and the latter effect dominates the former. In this case, the appeals process actually increases a low-cost firm's incentive to cheat. Therefore, the appeals process is valuable only if it is more accurate than the audit.

However, as we demonstrate below, if the regulator can undertake a more accurate investigation in the appeals process, the regulator would be better off by eliminating the appeals process and implementing the more accurate investigation in the audit.

To demonstrate the idea, we define $\Delta r = a - r$. Hence, from the above discussion, the appeals process (when implemented with certainty) reduces the low-cost firm's rent from mimicking a high-cost one by $\Delta I \equiv (1-r)ap - r(1-a)p \equiv \Delta rp$. Suppose the regulator implements the more accurate investigation in the audit. From our discussion in the previous section, the more accurate audit (when implemented with certainty) could reduce the low-cost firm's information rent by $[2(r+\Delta r)-1]p$ among which $2\Delta rp$ $(> \Delta I)$ is due to the increase in accuracy. Therefore, implementing the more accurate investigation in the audit leads to lower information rent for a low-cost firm than the appeals process does.

The intuition is the following. When the more accurate investigation is in the audit, the more accurate audit convicts a cheating low-cost firm with probability $r + \Delta r$ and a high-cost firm with probability $1-(r+\Delta r)$. In constrast, when the more accurate investigation is in the appeals process, eventually a cheating low-cost firm is punished with probability ra and a high-cost firm with probability $(1-r)(1-a)$. Since $(r+\Delta r)-(1-r-\Delta r) > ra-(1-r)(1-a)$ for $a > r$, the increased accuracy in the auditing increases the probability of punishing a cheating low-cost firm more than the appeals process does. Consequently, a more accurate audit is more effective than a more accurate appeals process in inducing truthful information from a low-cost firm.

Proposition 2 suggests that the appeals process becomes redundant when the regulator implements the more accurate investigation in the audit. Consequently, it is never optimal to implement the costless appeals process. We present this finding in Proposition 3.

Proposition 3 *It is never optimal to implement a costless appeals process.*

4.2 A costly appeals process

When the appeals process is costly, the effect of the appeals process depends on both the cost and the accuracy of the appeals process and on how the cost is allocated between the regulator and the appellant. Proposition 4 characterizes the optimal cost allocation between the regulator and the firm in the appeals process.

Proposition 4 *It is optimal for the principal to impose all the cost of the appeals process on the appellant.*[†]

The intuition underlying Proposition 4 is as follows. A cheating low-cost firm is less likely to be found innocent in the appeals process than a high-cost firm is. In other words, a cheating low-cost firm's expected benefit of appealing (the penalty is removed when found innocent) is smaller than that of a high-cost firm. Hence, imposing a larger share of the cost on the appellant can help deter a cheating low-cost firm from appealing. The appellant's cost of appealing can be viewed as a forfeitable bond that must be posted in order to appeal. The forfeitable bond helps separate different types of firms in the appeals process.

When the cost of the appeals process is substantial, the regulator can make a cheating low-cost firm indifferent between appealing or not (i.e., $(1-a)p = (1-\eta)Z$) by imposing a sufficiently large share of the cost on the appellant. After that point, further increase in the appellant's share of cost has no effect on social welfare. This is because after that point only a mistakenly accused high-cost firm has the incentive to appeal. Ultimately the regulator must compensate a high-cost firm's cost of appealing in the contract in order to

[†]Note the cost of the appeals process can be non-monetary resources such as time and effort needed to collect supporting evidence. Proposition 2 suggests that it can be optimal to impose a larger burden of proof on the appellant. It also suggests that, in a regulatory setting, the fact that regulatory hearings usually consume considerable time and resources does not necessarily imply that the process is inefficient. This offers another explanation for "regulatory bureaucracy". Sappington (1986) shows that regulatory bureaucracy, which hinders the regulator's ability to discern the firm's costs, creates incentives for the firm to reduce costs when the regulator does not have commitment power.

induce its participation. Therefore, the regulator at least weakly prefers the appellant to bear all the cost of the appeals process.

Although Proposition 4 suggests that it is optimal for the regulator to impose all the cost of the appeals process on the appellant, the regulator is often restricted from doing so for political or institutional reasons. Therefore we will consider η as exogenous for the regulator in our analysis. Moreover, we will limit our analysis to the case of $(1-a)p > (1-\eta)Z$ to better demonstrate the effect of η on the merit of the appeals process.

The first-order conditions of the regulator's optimization problem regarding $\underline{c}$, $\overline{c}$, $\underline{t}$, and $\overline{t}$ are given by equations (17), (18), (19), and (20). The first-derivative regarding θ is

$$\pounds_\theta = \mu_3(a-r)p + [\mu_3(1-\eta)(2r-1) - (1-v)(1-r)(1+\lambda)]Z. \tag{22}$$

The regulator implements the appeals process with certainty (i.e., $\theta = 1$) if $\pounds_\theta > 0$ but eliminates it completely if $\pounds_\theta < 0$. A comparison of equations (21) and (22) shows that the first term on the right-hand side of equation (22) measures the accuracy effect of the appeals process and the second term measures the cost effect of the appeals process. Notice that now the appeals process can be valuable (i.e., $\pounds_\theta > 0$) even if it is less accurate than the auditing (i.e., $a < r$) when the cost effect of the appeals process is positive.

When the appeals process is costly, the regulator must balance production efficiency, rent extraction and the cost of appeals process. Consequently, the regulator no longer enforces the efficient contract $\{\underline{c} = \underline{c}^*, \overline{c} = \overline{c}^*, \underline{t} = \psi(\underline{\beta} - \underline{c}^*), \overline{t} = \psi(\overline{\beta} - \overline{c}^*)\}$ regardless of the accuracy and the cost of the appeals process. In the optimal contract, a low-cost firm delivers the efficient level of effort but a high-cost firm delivers less than the efficient level of effort.

When $a > (1-r) + [\Delta\psi(e^{**}) - (2r-1)(1-\eta)Z]/L$, either the appeals process is sufficiently accurate or the cost of appealing, $(1-\eta)Z$, is sufficiently large for the appellant. (Notice that the right-hand side of the above inequality decreases as $(1-\eta)Z$ increases.) In this case, both types of firms receive no rent and a high-cost firm is required to deliver a level of effort between e^{**} and e^{*}.

When $a < (1-r) + [\Delta\psi(e^{**}) - (2r-1)(1-\eta)Z]/L$, a high-cost firm delivers the effort $\overline{e}^{**}$ and receives no rent but a low-cost firm receives a positive rent (which is smaller than that in L&T). The cost effect of the appeals process can be best demonstrated in this case. Since equation (20) indicates $\mu_3 = \lambda v$ in this case, the cost effect of the appeals process as indicated in equation (22) is $\lambda v(1-\eta)(2r-1)Z - (1-v)(1-r)(1+\lambda)Z$.

The first term demonstrates the positive effect of the cost of the appeals process. Since a high-cost firm is accused with probability $1-r$ and a cheating low-cost firm is accused with probability r by the audit, their expected costs of appealing are $r(1-\eta)Z$ and $(1-r)(1-\eta)Z$, respectively. Hence, the cost of the appeals process helps reduce the low-cost firm's rent from cheating by $(2r-1)(1-\eta)Z$ and increase the social welfare of the project by $\lambda v(1-\eta)(2r-1)Z$.

The second term demonstrates the negative effect of the cost of the appeals process. At equilibrium, only a mistakenly accused high-cost firm appeals. Therefore, an appeal occurs with probability $(1-v)(1-r)$ and then the expected social cost of the appeals process is $(1-v)(1-r)(1+\lambda)Z$. (Although the regulator bears only a share of the cost of the appeals process, she ultimately must compensate a high-cost firm's cost of appealing in order to induce its participation).

The cost effect of the appeals process is positive when $\lambda v(1-\eta)(2r-1) > (1-v)(1-r)(1+\lambda)$. More interestingly, the social welfare of the project increases as the cost of the appeals process increases in this case. Notice that this case arises when v and r are sufficiently large and η is sufficiently small. This is because of the following two reasons. First, rent extraction becomes more important as the firm is more likely to be of low-cost. Second, the cost of the appeals process has a larger impact on a cheating low-cost firm as the audit becomes more accuracy (so a cheating low-cost firm is more likely to be penalized by the auditing and utilize the appeals process) and the appellant is required to bear a larger share of the cost of appealing.

We summarize the above findings regarding the costly appeals process in Proposition 4.

Proposition 5 *When $L < \Delta\psi(e^*)/(2r-1)$ and the appeals process is costly, a) the regulator no longer implements the efficient contract regardless of the accuracy and the cost of the appeals process; b) the appeals process can be valuable even if it is less accurate than the auditing; c) social welfare can increase as the cost of the appeals process increases.*

5 Conclusion

It is well established that in standard adverse selection problems information rent can be eliminated and efficient production can be achieved when information that is correlated with the agent's private information can be made public ex post. However, the conclusion is drawn based on two assumptions. First, the principal can impose unlimited penalty on the agent when the ex post information is inconsistent with the agent's earlier revelation of its private information. Second, the agent cannot challenge the penalty even if it has in fact truthfully revealed its private information.

We introduce an imperfect audit and a subsequent appeals process into a standard adverse selection problem when legal or institutional restrictions impose an upper bound on penalties. We show that the imperfect audit always reduces the agent's information rent and enhances efficiency despite the limited liability. However, when the audit is sufficiently inaccurate and the penalty is restricted to be sufficiently small, the principal can no longer eliminate all of the agent's rent or achieve efficient production. The subsequent appeals process is never optimal when it is costless. However, when the appeals process is costly, we show that it can be optimal even if it is less accurate than the audit. Moreover, social welfare can increase as the cost of the appeals process increases.

Our analysis focuses on the effect of the appeals process on the agent's information revelation in adverse selection problems. We have ignored other possible merits of the appeals process. For example, Shavell (2006) shows that the appeals process constitutes a threat to adjudicators who would make socially undesirable decisions and therefore leads to the making of better decisions by adjudicators. Dai (2008) demonstrates the value of the appeals process when agent is averse to unfairness caused by evaluation errors. Future research that includes other merits of the appeals process into our consideration will be interesting.

6 Appendix A: Proof of Proposition 1.

The Lagrangian of the regulator's problem is

$$\begin{aligned} \pounds &= S - v[\lambda \underline{t} + (1+\lambda)\underline{c} + \psi(\underline{\beta} - \underline{c})] - (1-v)[\lambda(\overline{t} - \delta(1-r)p) + (1+\lambda)\overline{c} + \psi(\overline{\beta} - \overline{c})] \\ &\quad + \mu_1[\overline{t} - (1-r)[(1-\theta a)p + \theta(1-\eta)Z] - \psi(\overline{\beta} - \overline{c})] + \mu_2[\underline{t} - \psi(\underline{\beta} - \underline{c})] \\ &\quad + \mu_3[\underline{t} - \psi(\underline{\beta} - \underline{c}) - \overline{t} + \psi(\underline{\beta} - \overline{c}) + \delta rp] + \mu_4[L - p], \end{aligned} \tag{23}$$

where μ_1, μ_2, μ_3, and μ_4 are the Lagrange multipliers associated with constraints (6), (7), (8), and (10), respectively.[‡]

The first-order conditions regarding $\underline{c}$, $\overline{c}$, $\underline{t}$, $\overline{t}$, p, and δ are given by

$$\pounds_{\overline{c}} = (1-v)[\psi'(\overline{\beta} - \overline{c}) - (1+\lambda)] + \mu_1\psi'(\overline{\beta} - \overline{c}) - \mu_3\psi'(\underline{\beta} - \overline{c}) = 0, \tag{24}$$

[‡]It can be verified that the solution of the optimization problem under conditions (10), (6), (7), and (8) satisfies condition (9).

$$\pounds_{\underline{c}} = v[\psi'(\underline{\beta} - \underline{c}) - (1 + \lambda)] + \mu_2\psi'(\underline{\beta} - \underline{c}) + \mu_3\psi'(\underline{\beta} - \underline{c}) = 0, \tag{25}$$

$$\pounds_{\bar{t}} = -(1 - v)\lambda + \mu_1 - \mu_3 = 0, \tag{26}$$

$$\pounds_{\underline{t}} = -v\lambda + \mu_2 + \mu_3 = 0, \text{ and} \tag{27}$$

$$\pounds_p = (1 - v)\lambda\delta(1 - r) - \mu_1\delta(1 - r) + \mu_3\delta r - \mu_4 = 0. \tag{28}$$

The first-derivative regarding δ is

$$\pounds_\delta = [(1 - v)\lambda - \mu_1](1 - r)p + \mu_3 rp. \tag{29}$$

There are two valid cases to be analyzed.

Case 1. $\mu_4 = 0$.

When $\mu_4 = 0$, equations (26) and (28) together provides $\mu_3 = 0$. Then equation (26) indicates $\mu_1 = (1 - v)\lambda > 0$ and equation (27) indicates $\mu_2 = v\lambda > 0$. Then constraints (6) and (7) suggest that $\bar{t} - \delta(1 - r)p = \psi(\bar{\beta} - \bar{c})$ and $\underline{t} = \psi(\underline{\beta} - \underline{c})$. Substituting μ_1 and μ_2 into (24) provides $\psi'(\bar{\beta} - \bar{c}) = 1$; and substituting μ_2 and μ_3 into (25) provides $\psi'(\underline{\beta} - \underline{c}) = 1$.

The condition $\mu_3 = 0$ requires that constraint (8) must hold at $p = L$ and $\delta = 1$, which amounts to require that $r \geqslant 1/2 + \Delta\psi(e^*)/2L$.

Case 2. $\mu_4 > 0$.

When $\mu_4 > 0$, equations (26) and (28) together provides $\mu_3 = \mu_4/[(2r - 1)\delta] > 0$. Then equation (26) indicates $\mu_1 = (1 - v)\lambda + \mu_3 > 0$ and equation (27) indicates $\mu_2 = v\lambda - \mu_3$. Equation (24) provides

$$(1 - v)(1 + \lambda)[\psi'(\bar{\beta} - \bar{c}) - 1] = \mu_3[\psi'(\underline{\beta} - \bar{c}) - \psi'(\bar{\beta} - \bar{c})] < 0, \tag{30}$$

which implies $\psi'(\bar{\beta} - \bar{c}) < 1$; and equation (25) provides $\psi'(\underline{\beta} - \underline{c}) = 1$. Moreover, equation

(29) provides $\pounds_\delta = \mu_3(2r-1)p > 0$, i.e., $\delta = 1$.

Two sub-cases arise when $\mu_4 > 0$..

Subcase 2.1. $\mu_2 = 0$.

Since $\mu_3 = v\lambda$ when $\mu_2 = 0$, equation (27) provides

$$(1-v)(1+\lambda)[\psi'(\overline{\beta}-\overline{c})-1] = v\lambda[\psi'(\underline{\beta}-\overline{c})-\psi'(\overline{\beta}-\overline{c})], \tag{31}$$

which is the solution in a standard adverse selection without auditing. Let $\overline{c}^{**}$ denote the solution to the above equation. Then constraint (8) provides

$$\underline{t} = \psi(\underline{\beta}-\underline{c}^{**}) + \Delta\psi(e^{**}) - (2r-1)L, \tag{32}$$

which suggests that the auditing reduces the low-cost firm's information rent. The condition $\mu_2 = 0$ and $\mu_3 > 0$ requires that $r < 1/2 + \Delta\psi(e^*)/2L$.

Subcase 2.2. $\mu_2 > 0$

When $\mu_2 > 0$, $\mu_3 = v\lambda - \mu_2 < v\lambda$. From equation (30),

$$\frac{d\overline{c}}{d\mu_3} = \frac{\Delta\psi'(e)}{\mu_3\Delta\psi''(e)-(1-v)(1+\lambda)\psi''(\overline{\beta}-\overline{c})} > 0. \tag{33}$$

Therefore, $\mu_3 < v\lambda$ suggests that $\overline{c} < \overline{c}^{**}$. Then the binding constraint (8) provides $a = 1/2 + \Delta\psi(e)/(2L) > 1/2 + \Delta\psi(e^{**})/(2L)$.

7 Appendix B: A Costless Appeals Process

The Lagrangian of the regulator's problem is

$$\begin{aligned} \pounds &= S - v[\lambda \underline{t} + (1+\lambda)\underline{c} + \psi(\underline{\beta} - \underline{c})] - (1-v)[\lambda(\bar{t} - (1-r)(1-\theta a)p) \\ &\quad +(1+\lambda)\bar{c} + \psi(\overline{\beta} - \bar{c})] + \mu_1[\bar{t} - (1-\theta a)p - \psi(\overline{\beta} - \bar{c})] + \mu_2[\underline{t} - \psi(\underline{\beta} - \underline{c})] \quad (34) \\ &\quad +\mu_3[\underline{t} - \psi(\underline{\beta} - \underline{c}) - \bar{t} + \psi(\underline{\beta} - \bar{c}) + r(1-(1-a)\theta)p] + \mu_4[L - p]. \quad (35) \end{aligned}$$

The first-order conditions regarding $\underline{c}$, $\bar{c}$, $\underline{t}$, $\bar{t}$, and p are given by

$$\pounds_{\bar{c}} = (1-v)[\psi'(\overline{\beta} - \bar{c}) - (1+\lambda)] + \mu_1\psi'(\overline{\beta} - \bar{c}) - \mu_3\psi'(\underline{\beta} - \bar{c}) = 0, \quad (36)$$

$$\pounds_{\underline{c}} = v[\psi'(\underline{\beta} - \underline{c}) - (1+\lambda)] + \mu_2\psi'(\underline{\beta} - \underline{c}) + \mu_3\psi'(\underline{\beta} - \underline{c}) = 0, \quad (37)$$

$$\pounds_{\bar{t}} = -(1-v)\lambda + \mu_1 - \mu_3 = 0, \quad (38)$$

$$\pounds_{\underline{t}} = -v\lambda + \mu_2 + \mu_3 = 0, \text{ and} \quad (39)$$

$$\pounds_p = [(1-v)\lambda - \mu_1](1-r)(1-\theta a) + \mu_3 r[1-\theta(1-a)] - \mu_4 = 0. \quad (40)$$

The first-derivative regarding θ is

$$\pounds_\theta = [(\mu_1 - (1-v)\lambda)(1-r)a - \mu_3 r(1-a)]p. \quad (41)$$

There are two valid cases to be analyzed.

Case 1. $\mu_4 = 0$.

When $\mu_4 = 0$, equations (38) and (40) together provides $\mu_3 = 0$. Then equation (38) indicates $\mu_1 = (1-v)\lambda > 0$ and equation (39) indicates $\mu_2 = v\lambda > 0$. Then constraints

(12) and (13) suggest that $\bar{t} - (1-\theta a)p = \psi(\overline{\beta} - \bar{c})$ and $\underline{t} = \psi(\underline{\beta} - \underline{c})$. Substituting μ_1 and μ_2 into (36) provides $\psi'(\overline{\beta} - \bar{c}) = 1$; and substituting μ_2 and μ_3 into (37) provides $\psi'(\underline{\beta} - \underline{c}) = 1$.

The condition $\mu_3 = 0$ requires that constraint (8) must hold at $p = L$ and $\delta = 1$, which amounts to require that $a \geqslant (1-r) + \Delta\psi(e^*)/L$.

Case 2. $\mu_4 > 0$.

When $\mu_4 > 0$, equations (38) and (40) together provides $\mu_3 = \mu_4/[r(1-(1-a)\theta) - (1-r)(1-\theta a)] > 0$. Then equation (38) indicates $\mu_1 = (1-v)\lambda + \mu_3 > 0$ and equation (39) indicates $\mu_2 = v\lambda - \mu_3$. Equation (36) provides

$$(1-v)(1+\lambda)[\psi'(\overline{\beta} - \bar{c}) - 1] = \mu_3[\psi'(\underline{\beta} - \bar{c}) - \psi'(\overline{\beta} - \bar{c})] < 0, \tag{42}$$

which implies $\psi'(\overline{\beta} - \bar{c}) < 1$; and equation (38) provides $\psi'(\underline{\beta} - \underline{c}) = 1$. Moreover, equation (41) provides $\mathcal{L}_\theta = \mu_3[(1-r)a - r(1-a)]p > 0$, i.e., $\theta = 1$.

Two sub-cases arise when $\mu_4 > 0$.

Subcase 2.1. $\mu_2 = 0$.

Since $\mu_1 = \lambda$ and $\mu_3 = v\lambda$ when $\mu_2 = 0$, equation (27) provides

$$(1-v)(1+\lambda)[\psi'(\overline{\beta} - \bar{c}) - 1] = v\lambda[\psi'(\underline{\beta} - \bar{c}) - \psi'(\overline{\beta} - \bar{c})], \tag{43}$$

which suggests $\bar{c} = \bar{c}^{**}$. Then constraint (13) provides

$$\underline{t} = \psi(\underline{\beta} - \underline{c}^{**}) + \Delta\psi(e^{**}) - (a + r - 1)L. \tag{44}$$

The condition $\mu_2 = 0$ and $\mu_3 > 0$ requires that $a < (1-r) + \Delta\psi(e^*)/L$.

Subcase 2.2. $\mu_2 > 0$

When $\mu_2 > 0$, $\mu_3 = v\lambda - \mu_2 < v\lambda$. From equation (42), we have $d\bar{c}/d\mu_3 > 0$. Therefore, $\mu_3 < v\lambda$ suggests that $\bar{c} < \bar{c}^{**}$. Then the binding constraint (8) provide $a = (1-r) + \Delta\psi(e)/L > (1-r) + \Delta\psi(e^{**})/L$.

8 Appendix C: A Costly Appeals Process

The Lagrangian of the regulator's problem is

$$\begin{aligned}
\pounds \quad = \quad & S - v[\lambda\underline{t} + (1+\lambda)\underline{c} + \psi(\underline{\beta} - \underline{c})] - (1-v)[\lambda(\bar{t} - (1-r)(1-\theta a)p) \\
& +(1+\lambda)\bar{c} + \psi(\overline{\beta} - \bar{c}) + (1-r)\theta Z(1+\lambda\eta)] \qquad (45) \\
& +\mu_1[\bar{t} - (1-r)[(1-\theta a)p + \theta(1-\eta)Z] - \psi(\overline{\beta} - \bar{c})] + \mu_2[\underline{t} - \psi(\underline{\beta} - \underline{c})] \\
& +\mu_3[\underline{t} - \psi(\underline{\beta} - \underline{c}) - \bar{t} + \psi(\underline{\beta} - \bar{c}) + r(p - \theta\max\{0, (1-a)p - (1-\eta)Z\})] + \mu_4[L - p]. \qquad (46)
\end{aligned}$$

Suppose that $(1-a)p > (1-\eta)Z$, then the first-order conditions regarding $\underline{c}$, $\bar{c}$, $\underline{t}$, $\bar{t}$, and p are the same as those in the case of a costless appeals process. The first-derivative regarding θ is

$$\begin{aligned}
\pounds_\theta \quad = \quad & [(\mu_1 - (1-v))\lambda(1-r)a - (1-v)(1-r)\lambda a - \mu_3 r(1-a)]p \qquad (47) \\
& +[(\mu_3 r - \mu_1(1-r))(1-\eta) - (1-v)(1-r)(1+\lambda\eta)]Z.
\end{aligned}$$

Suppose the regulator can choose η. Then the first-order condition regarding η is

$$\pounds_\eta = [\mu_3 r + \mu_1(1-r) - (1-v)(1-r)\lambda)]\theta Z. \qquad (48)$$

There are two cases to be analyzed.

Case 1. $\mu_4 = 0$.

When $\mu_4 = 0$, we have $\mu_3 = 0$, $\mu_1 = (1-v)\lambda > 0$, and $\mu_2 = v\lambda > 0$ as shown in Appendix B. Then equation (47) suggests $\pounds_\theta = -(1-v)(1-r)(1+\lambda)Z < 0$, i.e., $\delta = 0$. However, Appendix A shows that in the absence of the appeals process $\mu_4 > 0$ when $L < \Delta\psi(e^*)/(2r-1)$.

Therefore, this case is no longer valid.

Case 2. $\mu_4 > 0$.

When $\mu_4 > 0$, we have $\mu_3 > 0$, $\mu_1 = (1-v)\lambda + \mu_3 > 0$, and $\mu_2 = v\lambda - \mu_3$ as shown in Appendix B. Then equation (48) provides $\pounds_\eta = \mu_3\theta Z > 0$ as long as $\theta > 0$, which proves Proposition 3. Moreover, equation (41) provides

$$\pounds_\theta = \mu_3(a-r)p + [\mu_3(2r-1)(1-\eta) - (1-v)(1-r)(1+\lambda)]Z. \tag{49}$$

Therefore, even if $a < r$, we have $\pounds_\theta > 0$ and $\theta = 1$ if.$[\mu_3(2r-1)(1-\eta) - (1-v)(1-r)(1+\lambda)]Z \geqslant \mu_3(r-a)p$. In this case, $\pounds_Z = [(\mu_3 r - \mu_1(1-r))(1-\eta) - (1-v)(1-r)(1+\lambda\eta)] > 0$, which suggests that social welfare increases in Z by the envelope theorem.

In addition, equation (36) implies $\psi'(\overline{\beta}-\overline{c}) < 1$; and equation (38) provides $\psi'(\underline{\beta}-\underline{c}) = 1$.

Two sub-cases arise when $\mu_4 > 0$.

Subcase 2.1. $\mu_2 = 0$.

Since $\mu_1 = \lambda$ and $\mu_3 = v\lambda$ when $\mu_2 = 0$, equation (27) provides

$$(1-v)(1+\lambda)[\psi'(\overline{\beta}-\overline{c}) - 1] = v\lambda[\psi'(\underline{\beta}-\overline{c}) - \psi'(\overline{\beta}-\overline{c})], \tag{50}$$

which suggests $\overline{c} = \overline{c}^{**}$. Then constraint (13) provides

$$\underline{t} = \psi(\underline{\beta} - \underline{c}^{**}) + \Delta\psi(e^{**}) + (1-2r-\theta(a-r))L + (1-2r)\theta(1-\eta)Z. \tag{51}$$

The condition $\mu_2 = 0$ and $\mu_3 > 0$ requires that $a < (1-r) + \Delta\psi(e^*)/L + (1-2r)(1-\eta)Z/L$.

Subcase 2.2. $\mu_2 > 0$

We have $\mu_3 = v\lambda - \mu_2 < v\lambda$ when $\mu_2 > 0$. As equation (42) implies $d\overline{c}/d\mu_3 > 0$, $\mu_3 < v\lambda$ suggests $\overline{c} < \overline{c}^{**}$. Then the binding constraint (8) requires $a > (1-r) + \Delta\psi(e^{**})/L + (1-2r)(1-\eta)Z/L$.

The analysis for the case of $(1-a)p > (1-\eta)Z$ is similar and is omitted.

9 Reference

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