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ABSTRACT

Third Party Monitoring and Golden Parachutes*

When today's actions can affect tomorrow's value of an asset and when the principal does not have access to hard information, either about productive activity or monitoring activity, two incentive problems must be simultaneously solved: first, the *ex ante* moral hazard problem of inducing higher productive effort from the agent; second, the *ex post* problem of inducing auditing and revelation of information from the auditor. Somewhat surprisingly, the first best can be attained in the negative externality (higher effort decreases the expected future quality of the asset) case: it is enough for the principal to commit to reallocate the right to use the asset at the end of the first period. In the positive externality case (when higher effort increases the future expected quality of the asset) a change in the rights to use the asset is no longer sufficient for efficiency in the second best situation. Rather, auditing by a potential entrant becomes necessary and a mix of property rights reallocation and transfers is necessary to solve the two incentive problems. We show that the second best optimal takes the form of a generalized 'golden parachute' contract where for high outputs the agent is replaced by the third party and leaves with a fixed compensation.

JEL Classification: D62, D82, L33, L51
Keywords: externality, golden parachutes, monitoring, regulation

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NON-TECHNICAL SUMMARY

The quality of information is crucial for designing efficient incentive schemes. Quite generally, ‘better’ information allows the design of ‘better’ incentive schemes, i.e. schemes that reduce the inefficiencies linked to the informational rents of the agent (Holmström, 1979). However, information about the performance of an agent is often obtained by other agents who are themselves subject to opportunistic behaviour. Hence, hiring an agent to monitor the performance of another agent can yield new incentive problems; in particular that agent has to be provided with the right incentives to monitor and to reveal the result of his monitoring.

We analyse the problem of a principal who does not have access to hard information, either about productive activity or monitoring activity and who faces two incentive problems: first, the *ex ante* moral hazard problem of inducing higher productive effort from the agent; second, the *ex post* problem of inducing auditing effort and revelation of information of the audit outcome from the third party. The principal can use two instruments to solve his problem: monetary instruments (net payments to the agents) and property right instruments (more precisely the right to use an asset).

As in standard principal agent models, higher effort levels generate higher expected revenues from future use of the asset. However, our principal is also concerned with the quality of the asset and higher effort levels can either increase or decrease the expected future quality of the asset. As long as the agent has full property rights on the future use of the asset he would like high revenues but the principal would also like high quality. If effort creates a negative externality on quality, the revenue motive and the quality motives conflict with each other. If effort creates a positive externality on quality the two motives are consistent with each other; but this does not imply that incentive problems are absent.

Somewhat surprisingly, the negative externality case turns out to be the simplest. The threat of expropriation is indeed enough to create first best incentives. Moreover, there is no value to information about the agent’s performance and hence no value to induce a third party to audit. It is enough to use a non-state contingent threat of change in property rights to generate the right incentives; the possibility of losing the future use of the asset reduces the stake for the agent from exerting effort.

Instead, when there is a positive externality, third party auditing becomes necessary in order to improve upon inadequate private incentives, and a specific combination of property rights and monetary rights needs to be used to maximize the principal’s welfare. In this case, the optimal contract generalizes ‘golden parachutes’ contracts: if the third party gains the right to use the asset the agent receives a fixed compensation (a golden parachute),

while if the agent keeps the right to use the asset he receives a variable compensation based on his performance. Whether or not the agent keeps the right to use the asset is a function of the state that is revealed by the third party: for low states, the agent keeps the right, otherwise the third party obtains this right.

Having a change of rights when second period states are high might seem counter-intuitive. Indeed, the monotone likelihood ratio property suggests that the agent should be rewarded if there are good news about his performance and should be punished if there are bad news. This ignores the fact that each instrument is best to respond to one of the two incentive problems: property rights is the 'effective' instrument for the *ex post* problem of the entrant and monetary compensation is the effective instrument for the *ex ante* problem of the incumbent. Once the third party gathers information and truthfully reveals it, monetary compensation is indeed used in a way that is consistent with standard theory: pay-offs are high for high output states and low for low output states. However, monetary pay-offs cannot be used to induce information gathering from the third party unless their pay-off varies with the state of the world. In particular, in order to avoid that the third party always reports bad news without even gathering information it is necessary that they acquire the right to use the asset only if they obtain good news.

Our model is quite stylized but we feel that our conclusions are useful in a variety of environments. The model is directly applicable to many issues in regulation and suggests a new role for outsourcing (or threat to outsource): the entrant is used as a means to generate information that is correlated with the future value of the asset.

A direct application of the case of positive externalities is to environmental policy in less-developed countries. Suppose that the incumbent is a firm that has currently the right to use a natural resource (e.g. a forest), to produce a marketable good (e.g. timber) and that the entrant is another firm that would like to have the right to use the resource. The State is the principal who wants to preserve the resource (say for ecological reasons) while at the same time raise revenues by having firms pay for the right to use the resource. The operator can take steps for tree planting, fertilizing, disposing of slash, etc. in order to correct the effects of harvesting. Because technologies and corrective measures (replanting) are also costly, an operator has little incentives to invest into technologies or to exert effort to a level that will be socially efficient. Monitoring could be done by an agency, like the forest bureau in the US, and incentives to gather and to reveal information could be internalized in this agency. However, for many developing countries in which these natural resources represent a large part of the national income, the provision of incentives inside agencies is weak (for reasons having to do with weak institutions in general, limited budget for monitoring or corruption). Our analysis suggests that the combination of a periodic auction of the right to use the resource and compensation to the incumbent if he loses the right could be another solution to the monitoring problem for these countries. Moreover, the mechanism is economical to implement since it requires only a change of rights and fixed payments.

1 Introduction

The quality of information is crucial for designing efficient incentive schemes. Quite generally, "better" information allows the design of "better" incentive schemes, i.e., schemes that reduce the inefficiencies linked to the informational rents of the agent (Holmström 1979). However, information about the performance of an agent is often obtained by other agents who are themselves subject to opportunistic behavior. Hence, hiring an agent to monitor the performance of another agent can yield new incentive problems; in particular that agent has to be provided with the right incentives to monitor *and* to reveal the result of his monitoring.

We analyze the problem of a principal who does not have access to hard information, either about productive activity or monitoring activity and who faces two incentive problems: first, the "ex-ante" moral hazard problem of inducing higher productive effort from the agent; second, the "ex-post" problem of inducing auditing effort *and* revelation of information of the audit outcome from the third party. The principal can use two instruments to solve his problem: monetary instruments (net payments to the agents) and property right instruments (more precisely the right to use an asset).

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Both cases are relevant. Suppose for example that the asset is a marketable good, like a natural renewable resource allowed for private exploitation, or a public firm prior to privatization and that the government's objective is to maximize the social non-monetary benefits from the asset. In this case the principal (government) will wish to reduce the agent's incentives to use economical non-environmental friendly technologies, or to engage in cost-cutting activities that have a negative impact on safety and quality standards. Consequently, private and public incentives are in conflict: the agent's activity generates a negative externality on the principal's payoff. Instead, positive externalities may arise when the agent's effort is interpreted as investment in resource maintenance activity or in quality/safety improvements. Since effort increases both the future revenues from the asset and its non-monetary benefits, the agent and the principal's incentives would be aligned were the former allowed to retain the asset in future periods.

Somewhat surprisingly, the negative externality case turns out to be the simplest. The threat of expropriation is indeed enough to create first best incentives. Moreover, there is no value to information about the agent's performance and hence no value to induce a third party to audit. It is enough to use a non-state contingent threat of change in property rights to generate the right incentives; the possibility of losing the future use of the asset reduces the stake for the agent from exerting effort.

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Having a change of rights when second period states are *high* might seem counter-intuitive. Indeed, the monotone likelihood ratio property suggests that the agent should be rewarded if there are good news about his performance and should be punished if there are bad news. This ignores the fact that each instrument is best to respond to one of the two incentive problems: property rights is the "effective "instrument for the ex-post problem of the entrant, and monetary compensation is the effective instrument for the ex-ante problem of the incumbent. *Once* the third party gathers information and truthfully reveals it, monetary compensation is indeed used in a way that is consistent with standard theory: payoffs are high for high output states and low for low output states. However, monetary payoffs *cannot be used* to induce information gathering from the third party unless her payoff varies with the state of the world. In particular, in order to avoid that the third party always reports bad news without even gathering information it is necessary that she acquires the right to use the asset only if she obtains good news.

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A direct application of the case of positive externalities is to environmental policy in less developed countries. Suppose that the incumbent is a firm that has currently the right to use a natural resource (e.g., a forest), to produce a marketable good (e.g., timber) and that the entrant is another firm which would like to have the right to use the resource. The State is the principal who wants to preserve the resource (say for ecological reasons) while at the same time raise revenues by having firms pay for the right to use the resource. The operator can take steps for tree planting, fertilizing, disposing of slash, etc., in order to correct the effects of harvesting. Because technologies and corrective measures (replanting) are also costly, an operator has little incentives to invest into technologies or to exert effort to a level that will be socially efficient. Monitoring could be done by an agency, like the forest bureau in the U.S., and incentives to gather and to reveal information could be internalized in this agency. However, for many developing countries in which these natural resources represent a large part of the national income, the provision of incentives inside agencies is weak (for reasons having to do with weak institutions in general, limited budget for monitoring or corruption). Our analysis suggests that the combination of a periodic auction of the right to use the resource and a compensation to the incumbent if he loses the right could be another solution to the monitoring problem for these countries. Moreover, the mechanism is economical to implement since it requires only a change of rights and fixed payments.

The rest of the paper is organized as follows. We introduce the model in Section 2 and consider both the benchmark case in which there is no potential entrant (Section 2.1), and when there is an outside source (Section 2.2). We analyze the respective roles of property rights and monetary compensations in Section 3.1. We focus in Section 3.2 on the case of positive externalities where we derive the properties of the optimal mechanism. We discuss the relevant literature and some extensions in Section 4. All proofs are relegated to the appendix.

2 The model

An incumbent has the current right to use an asset (or a resource). The "state" of the asset is indexed by R, $R \in \left[\underline{R}, \overline{R}\right]$ and for simplicity R is also the market value when the asset is used for production. There are two periods, 1 and 2. In period 1, the value of the asset is known and the use of the asset yields a revenue R_0 *if exploited* by some firm (otherwise the revenue is zero) and a social benefit $V_0 = V\left(R_0\right)$. In the first period, the firm that has the right to use the asset takes an action e that modifies the distribution of $F(R, e)$ of the second period revenue R. This revenue is realized only if some firm exploits the resource, but neither the firm nor the regulator can observe it at the beginning of period 2. We make the usual assumptions $F_e \leq 0$, $F_{ee} \geq 0$ and that the monotone likelihood ratio property (MLRP) holds: $\frac{\partial}{\partial R}\frac{f_e(R,e)}{f(R,e)} \geq 0$. We assume that 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 resource "higher" but also make the cost $\phi\left(e\right)$ to the firm larger, where $\phi' > 0$, $\phi'' > 0$.

The mean revenue is

$$\rho\left(e\right) = \int_{\underline{R}}^{\overline{R}} RdF\left(R, e\right),$$

and integration by parts shows that $\rho'\left(e\right) > 0$ and $\rho'' \leq 0$ in light of $F_e \leq 0$, $F_{ee} \geq 0$, respectively.

The status of the resource affects not only the revenue that a firm can obtain from exploiting it but also the social non-monetary benefits that the resource will generate. To simplify, we assume that if the state is R, the social benefit is a function $V(R)$. We distinguish between two cases, (a) $V'(R) < 0$; (b) $V'(R) > 0$.[1] Defining the mean social benefit as

$$\sigma(e) = \int_{\underline{R}}^{\overline{R}} V(R)\, dF(R, e).$$

it follows, after integration by parts, that $\sigma'(e) < 0$ when $V'(R) < 0$ and $\sigma'(e) > 0$ when $V'(R) > 0$. In case (a), $\sigma'(e) < 0$ and e could be interpreted as the firm's use of biological control (*e.g* use of pesticides, genetically modified crops, introduction of exotic species) or the extent of monoculture; these increase future revenues at the expense of the environment. Instead, case (b) where $\sigma'(e) > 0$ could arise when e represents investment in maintenance activity, e.g. tree planting, fertilizing, disposing of slash etc. Hence, higher levels of e allow a better preservation of the resource and increase both the future revenues that can be generated by its exploitation and the social benefits.

We further assume that the government has limited funding, $z \geq 0$, and that there is a cost $(1+\lambda)$, where $\lambda > 0$, of *giving* \$1 to a firm; this cost embodies distortions due to taxation. Transfers from a firm to the state are then valued at $(1+\lambda)$ since the state "saves" the shadow price of taxation λ. (Introducing $\lambda > 0$ make the government trade-off social benefits versus revenues.). The State maximizes the sum of the social benefit, profits of the firm taking into account the opportunity cost λ of levying taxes. For simplicity we assume that the discount factor is equal to 1. The firm is risk neutral and maximize its net profit function. Finally, we assume that at the beginning of period 1 the government can commit to any long term mechanisms specifying the contractual conditions applying to period 1 and 2. However, the firm can turn down the contract at no costs (e.g. by running away) at the beginning of period 2. This implies that an interim rationality constraint, which ensures a non negative utility to the firm conditioned on the information available, must hold at the beginning of each of the two periods of the game.

2.1 No potential entrant

2.1.1 Benchmark 1: contractible effort

Suppose first that e is contractible. A contract specifies a transfer s_0 that the incumbent pays the State and a probability x_0 with which the incumbent obtains the asset, in the first period; and a transfer $s(e)$ and a probability $x(e)$ in the second period. Because of the assumption that the expected rent of the firm, conditioned on the information available, must be non-negative in each period, the following constraints apply: $x_0 R_0 - s_0 - \phi(e) \geq 0$ and $x(e)\rho(e) - s(e) \geq 0$.

[1] This is without much loss of generality. More generally, one might assume that if θ is the quality variable, choices of effort by the incumbent defines a distribution $H(\theta; e)$. Subsequently, the revenue in the second period is a random variable R with distribution $F(R;\theta)$ and the social benefit is a random variable V with distribution $G(V;\theta)$. As long as $H_e < 0$, $F_\theta < 0$ and $G_\theta \lesseqgtr 0$ - according to whether we are in case (a) or (b) -, the qualitative results of the paper will hold.

Since e is contractible, the regulator's maximization program is given by:

$$\max_{x_0,x,s,s_0,e} V_0 + \lambda s_0 + x_0 R_0 - \phi(e) + \int_{\underline{R}}^{\overline{R}} [V(R) + xR]\, dF(R,e) + \lambda s$$

$$s.t. \quad x_0 R_0 - s_0 - \phi(e) \geq 0$$
$$x\rho(e) - s \geq 0$$
$$s, s_0 \geq -z$$
$$0 \leq x_0, x \leq 1$$

It is immediate that in optimum $x_0 = 1$ and $s_0 = R_0 - \phi(e)$ (which for R_0 sufficiently high satisfies the constraint $s_0 \geq -z$) therefore hereafter we will ignore the first period transfer and property rights and focus on the second period regulator's payoff, taking into account that the cost of effort is $(1+\lambda)\phi(e)$.

Hence, the above problem boils down to

$$\max_{x,s,e} \int_{\underline{R}}^{\overline{R}} [V(R) + xR]\, dF(R,e) + \lambda s - (1+\lambda)\phi(e)$$

$$s.t. \quad x\rho(e) - s \geq 0$$
$$s \geq -z$$
$$0 \leq x \leq 1$$

The solution of which is obtained at $x^{FB} = 1$, $s^{FB} = \rho\left(e^{FB}\right)$ and e^{FB} solving the equation

$$\sigma'\left(e^{FB}\right) + (1+\lambda)(\rho'\left(e^{FB}\right) - \phi'\left(e^{FB}\right)) = 0 \tag{1}$$

Notice that when $\sigma'(e) < 0$, private and social interests are in conflict: effort increases expected revenues, which have a positive weight in the welfare function because of the shadow cost of public funds, but generates a negative externality to consumers. Instead, when $\sigma'(e) > 0$, private and social interests are aligned: both consumer surplus and revenues increase with e.

2.1.2 Benchmark 2: unverifiable effort

Suppose now that e is not verifiable. Since R is not observable, the only possible contracts are those that specify non-contingent values for the probability x and the transfer s. Faced with such a contract, the firm chooses e in the first period to solve

$$\max_e x\rho(e) - s - \phi(e)$$

or

$$x\rho'(e) = \phi'(e).$$

Let e^0 be the effort level that equalizes the marginal revenue and the marginal cost of effort: $\phi'\left(e^0\right) = \rho'\left(e^0\right)$. Comparing to (1), it is immediate that $e^0 > e^{FB}$ if $\sigma' < 0$ (case a) and $e^0 < e^{FB}$ if $\sigma' > 0$ (case b): when the agent has full property rights, he will over-provide effort when the revenue and quality motives are in conflict and will under-provide effort when the two motives are aligned.

The State chooses x and s to solve

$$\begin{gathered}\max_{x,s} \sigma(e) + x\rho(e) + \lambda s - (1+\lambda)\phi(e) \\ s.t. \quad x\rho'(e) = \phi'(e) \\ x\rho(e) - s \geq 0 \\ s \geq -z \\ 0 \leq x \leq 1\end{gathered}$$

In case (a) when $\sigma'(e) < 0$ but not too negative, the solution is internal with $\widetilde{s} = \widetilde{x}\rho(\widetilde{e})$, and $\widetilde{e}$ and $\widetilde{x}$ solving

$$\begin{gathered}-\frac{\rho'(e)\,\sigma'(e)}{x\rho''(e) - \phi''(e)} + (1+\lambda)\rho(e) = 0 \\ \phi'(e) = x\rho'(e)\end{gathered} \tag{2}$$

with $\widetilde{x} \in (0,1)$.[2] Note that there is *over-provision of effort* since in an interior or a corner solution $\tilde{e} > e^{FB.}$

The intuition behind this result is straightforward. In the welfare function, both revenues and non-monetary social benefits enter as positive terms, where effort increases the former but decreases the latter. Since the equilibrium level of effort is an increasing function of x with $e(0) = 0$ and $e(1) > e^{FB}$, the optimal allocation of property rights is dictated by the relative effect of effort on $\sigma(e)$ and on $\rho(e)$ (evaluated at the shadow cost of public funds).

Now, consider case (b), where $\sigma'(e) > 0$. The solution is $x^M = 1$, $s^M = \rho\left(e^0\right)$, and $e^M = e^0$ with $e^M < e^{FB}$. Hence, with only one firm, it is not possible to induce the firm to internalize the positive externality that it creates on consumers by taking effort today, and this yields *under-provision of effort.*

In the next section we introduce potential competition for the right to exploit the resource. Later, we will analyze when the existence of a potential entrant is desirable. Note that, since we do not allow for any difference in productive

[2] This is obtained by noticing that, in light of $\widetilde{s} = x\rho(\widetilde{e})$, $\widetilde{x}$ maximizes: $\sigma(e(x)) - (1+\lambda)(x\rho(e(x)) - \phi(e(x)))$ subject to $0 \leq x \leq 1$ and $e(x)$ solving $\phi'(e) = x\rho'(e)$. Taking the derivative of the objective function w.r.t. x, we obtain

$$\left[-\frac{\rho'(e)\,\sigma'(e)}{x\rho''(e) - \phi''(e)} + (1+\lambda)\rho(e)\right] + \xi \leq 0$$

where ξ is the Lagrangian multiplier of $x \leq 1$. Hence if the term in square bracket is negative (positive), then $\widetilde{x} = 0$ and $\widetilde{e} = 0$ (respectively, $\widetilde{x} = 1$ and $\widetilde{e} = e^0$) if instead there exists an internal solution then $\widetilde{x}$ solves (2).

efficiency between the entrant and the incumbent, entry may be desirable only if it modifies the incentives of the incumbent in the first period.

2.2 Existence of a potential entrant

We assume that at the beginning of period 2, another firm (the *entrant*) can collect information about the state of the resource (by sampling for instance): at a cost $C(r)$, the entrant learns the realized value R with probability r and nothing with probability $1-r$. The information collected by the entrant is "soft", that is, there is nothing tangible that can be used to transmit the information in a credible way.

Standard mechanism design reasoning tells us that the problem of revelation can be modeled by a direct revelation mechanism that specifies the property rights of the two firms and the side payments as a function of the state that the entrant announces. In the present context, the entrant can either observe the true quality or nothing, hence it will announce an element $R^E \in \left[\underline{R}, \overline{R}\right] \cup N$, where N stands for "nothing".[3] Let (y,t) be the probability and the side payment maps for the entrant and (x,s) be the probability and the side payment maps for the incumbent. We denote respectively by $U^E\left(R, R^E\right) = y(R^E)R - t(R^E)$ and $U^E\left(N, R^E\right) = y(R^E)\rho(e) - t(R^E)$ the entrant's payoff when it observes the true state and when it observe nothing, given the announced value $R^E \in \left[\underline{R}, \overline{R}\right] \cup N$. Finally, we assume that after having gathered information and observed R of $\left[\underline{R}, \overline{R}\right] \cup N$, the entrant can turn down the contract at no costs. This yields the constraint $U^E(R) \geq 0$ for all $R \in \left[\underline{R}, \overline{R}\right] \cup N$.

The information collected by the entrant may be valuable to the state because, if revealed, it becomes common knowledge and can be used as an incentive contract with the *incumbent*. Hence, while spot contracts cannot generate incentives, dynamic contracts in which the incumbent's second period right to use the asset and side payment are contingent on the information revealed by the entrant could generate incentives.[4] In particular, due to entrant truthfully revealing $R \in \left[\underline{R}, \overline{R}\right] \cup N$, the incumbent expected utility (net of sunk costs) becomes

$$EU^I(R,e,r) = r\int_{\underline{R}}^{\overline{R}} \left[x(R)R - s(R)\right] dF(R,e) + (1-r)\left[x(N))\rho(e) - s(N)\right] \tag{3}$$

[3] In fact, the mechanism could also ask the entrant the amount invested in information gathering. However, because the entrant has already spent $C(r)$ and has already observed R or "nothing", the incentive problem is the same for all values of r which makes mechanisms contingent on r useless.

[4] Notice that our mechanism can be reinterpreted as an option contract, where the government sells the resource to the incumbent in the first period but keeps the option to pay it back in the subsequent period. Clearly, in any case the government needs to be able to commit to the long term contract for the mechanism to be implementable.

which shows that now the State has the additional instrument of $s(R)$ to provide incentives. Moreover, the expected welfare becomes

$$EW(e,r,R,x,y,s,t) = \sigma(e) - \phi(e)(1+\lambda) - C(r) + r[\int_{\underline{R}}^{\overline{R}} (y(R)+x(R))R+$$

$$\lambda(s(R)+t(R))]dF(R,e) + (1-r)[(y(N)+x(N))\rho(e) + \lambda(s(N)+t(N))] \quad (4)$$

It follows, that the State's maximization program in the presence of potential entry can be written as follows:

$$\max EW(e,r,R,x,y,s,t)$$

$$s.t.$$

$$x(R)R - s(R) \geq 0 \qquad \text{for } R \in [\underline{R},\overline{R}] \cup N \quad (5)$$

$$y(R)R - t(R) \geq 0 \qquad \text{for } R \in [\underline{R},\overline{R}] \cup N \quad (6)$$

$$y(R^E)R - t(R^E) \qquad \text{for } R, R^E \in [\underline{R},\overline{R}] \cup N; R \neq R^E \quad (7)$$

$$e \in \arg\max r \int_{\underline{R}}^{\overline{R}} (x(R)R - s(R))\, dF(R,e) + (1-r)[x(N)\rho(e) - s(N)] - \phi(e) \quad (8)$$

$$r \in \arg\max r \int_{\underline{R}}^{\overline{R}} (y(R)R - t(R))\, dF(R,e) + (1-r)[y(N)\rho(e) - t(N)] - C(r) \quad (9)$$

$$s(R) \leq -z \qquad \text{for } R \in [\underline{R},\overline{R}] \cup N \quad (10)$$

$$0 \leq x(R), y(R) \leq 1 \qquad \text{for } R \in [\underline{R},\overline{R}] \cup N \quad (11)$$

where $EW(e,r,R,x,y,s,t)$ is given by expression (4). Expressions (5) and (6) represent the interim participation constraints of the incumbent and the entrant, respectively, while expression (7) is the incentive compatibility constraint for truth-telling of the entrant. Expressions (8) and (9) are the moral hazard constraints of the incumbent and of entrant the , respectively. Expressions (10) and (11) are the resource allocation constraints.

3 The Optimal Mechanisms

3.1 The Role of Property Rights and Monetary Compensations

In principle, there are two possible instruments that can be used to provide the right incentives: property rights and monetary payoffs. However, how these instruments combine within the optimal regulatory mechanism is crucially dependent on whether the externality is positive or negative. To see this, let us look at the two possible cases in more detail.

- *Case (a): negative externality $\sigma'(e) < 0$*

Despite the fact that when $\sigma'(e) < 0$ revenue and quality motives are in conflict, it is easy for the regulator to provide the correct incentives to the incumbent firm. Indeed, a simple continuity argument shows that there exists a value of x, denoted by $\widehat{x}$, with $0 \leq \widehat{x} < 1$, such that $e(\widehat{x}) = e^{FB} \geq 0$: the regulator can implement the first best level of effort by an appropriate choice of property rights. However, with only one firm, this is costly since any $x < 1$ generates a reduction in the expected revenues that the government can raise from the sale of property rights on the resource. This suggests that there is a potential gain from introducing competition for the right to exploit the resource and carefully allocate property rights. In fact by letting a second source replace the incumbent with probability $(1 - \widehat{x})$ at a price $t = \rho\left(e^{FB}\right)$, the regulator can dissipate the negative effect on revenues due to $\widehat{x} < 1$.

In short, contrary to what intuition might have suggested, when the revenue and the quality motives are in conflict, it is easy to align them. In particular, property rights alone to the incumbent can induce the first best when potential entry is allowed. Consequently, there is no value to third party monitoring.

- *Case (b): positive externality $\sigma'(e) > 0$*

To improve upon e^M, it is necessary that the payoff of the incumbent is contingent on a signal that is correlated with the time 2 quality *and* that can be used in contracting. A standard response to moral hazard is to invest into control structures or auditing. For instance, the state could create a forest bureau where the agents are responsible for reporting on the state of the forest. Such an audit activity is not likely to yield “hard” information and contracting must rely on what the agents in the forest bureau tell about the quality of the forest. If the agents themselves are subject to a moral hazard problem (time spent in the forest, etc.) it is not likely that the communication between the forest bureau and the state will yield information that can be used for contracting. In fact, as we will show below, if the agents are only compensated by monetary payoffs, then society cannot improve upon e^M. If auditing is to be effective, the auditors must directly value the information that they obtain. The only way to achieve this is by assigning property rights to the third party, therefore the role of the monitor needs to be played by the potential entrant.

When the revenue and quality motives are aligned, monetary payoffs may help *provided* that they are accompanied by property rights. From now on we analyze this case.

3.2 Positive Externality: Preliminary Facts

In this section we collect some simple facts, proven in the Appendix, that are meant to provide the intuition as to how the interplay between the two moral hazard problems of the incumbent and the entrant as well as the revelation problem of the entrant resolve in the characteristics of the optimal mechanism. In particular, we will establish as follows. First, monetary payoffs and property rights are not always interchangeable instruments to provide incentives. In fact, the unobservability of effort in information gathering together with the information being soft makes it impossible to induce information collection by the third party, unless its payoff varies with the state of the world. This implies that property rights needs to be dictated by the moral hazard problem of the entrant and in particular entry should be allowed when the entrant reveals good news. Second, once the information acquisition and the revelation problems are solved, monetary payoffs can be effective in disciplining the incumbent, by rewarding it when good news is reported.

Let us now look at these preliminary facts.

- **FACT 1.** $U^E(R) = \int_{\underline{R}}^{R} y(R)\,dR$ and $U^E(N) = \int_{\underline{R}}^{\rho(e)} y(R)\,dR$, which implies that the expected rent of the entrant (net of sunk costs) can be written as

$$EU^E(R,e,r) = r\int_{\underline{R}}^{\overline{R}} y(R)\,(1-F(R,e))dR + (1-r)\int_{\underline{R}}^{\rho(e)} y(R)\,dR \qquad (12)$$

Fact 1 follows from the entrant's incentive compatibility conditions for truth-telling. The entrant has incentives to under-report the value of the resource in order to save on the price it has to pay to acquire property rights. In particular, when the entrant observes R and reveals R^E, it gains a rent proportional to $y(R^E)(R-R^E)$, which explains the expression for $U^E(R)$. Instead, when the entrant observes nothing, it is as if it had observed $\rho(e)$, which implies $U^E(N)$ $= U^E(\rho(e))$ as stated above.

- **FACT 2**. $x(R)+y(R)=1$, for all $R \in [\underline{R},\overline{R}] \cup N$

Recall that the regulator has two main objectives: to induce the optimal choice of e and r and increase revenues. Other things equal, an increase in $x(R)$ $(y(R))$ increases the payoff of the incumbent (entrant) by R. Consequently, the government can proportionally increase the price the firm pays in state R, increase total revenues and keep the optimal choice of e (r) unchanged.

- **FACT 3.** Given $x(R)$, $s(R)$ for $R \in [\underline{R},\overline{R}] \cup N$ and r, e solves:

$$r\int_{\underline{R}}^{\overline{R}} [x(R)\,R - s(R)]\,dF_e(R,e) + (1-r)\,x(N)\rho'(e) - \phi'(e) = 0 \qquad (13)$$

The above expression represents the first order condition of the incumbent's maximization problem.

- **FACT 4.** There exists a level of R, denoted with R_M, where $\underline{R} < R_M <$ $\overline{R}$, such that

$$
\begin{aligned}
s(R) &= x(R)R, \text{for all } R < R_M \\
s(R) &= -(z + t(R)), \text{for all } R > R_M \\
s(N) &= x(N)\rho(e)
\end{aligned}
$$

where, in light of Fact 1 and 2, $t(R) = \underline{R} - x(R)R + \int_{\underline{R}}^{R} x(\tilde{R})d\tilde{R}$ and $t(N) = (1 - x(N))\rho(e) - \int_{\underline{R}}^{\rho(e)} (1 - x(R))dR$ since $t(R) = -U^E(R) + (1 - x(R))R$ for $R \in \left[\underline{R}, \overline{R}\right] \cup N$.

The above reward function follows from the combination of risk neutrality, liability constraints and MLRP. In particular, MLRP implies that higher efforts increase probability weights placed on high outcomes, thus maximal payoffs in high states maximize effort. Ideally, due to the risk neutrality of the agent it would be desirable to offer him a "huge" compensation when the maximum outcome is reached and nothing otherwise. However, since the principal is subject to wealth constraints, he will have to "distribute" his available funding over a wider range of high states.[5]

- **FACT 5**. For given level of e, there exists a unique value of R_M that implements it. Two different regimes may result in equilibrium: *Regime 1*, $R_M < \rho(e)$; *Regime 2*, $R_M > \rho(e)$.
- **FACT 6**. For given level of e and $x(R)$, r solves

$$
\int_{\rho(e)}^{\overline{R}} (1 - x(R))(1 - F(R, e))dR - \int_{\underline{R}}^{\rho(e)} (1 - x(R))F(R, e)\, dR - C'(r) = 0 \quad (14)
$$

The above expression represents the first order condition of the entrant's maximization problem. Notice that due to the concavity of $EU^E(R, e, r) - C(r)$ w.r.t. r, at the optimum the individual rationality constraint of the entrant, $EU^E(\cdot) - C(r) \geq 0$, is satisfied and therefore can be disregarded.

3.2.1 Generalized Golden Parachute Contracts

Before proceeding to analyze the characteristics of the optimal mechanism, it is useful to highlight the importance of property rights in providing incentives for third party monitoring.

Proposition 1 *When effort in information collection is costly and unverifiable, the principal cannot rely on an auditor (a third party with no property rights) for information gathering.*

[5] A similar result is obtained by Innes (1990).

The intuition is straightforward: because the entrant's effort is costly and unverifiable, it will have incentives to audit only if its payment is a non-constant function of the information that it reveals. However, because information is not hard, if the compensation is variable, the entrant always has an incentive to report the contingency that maximizes its compensation, which contradicts the fact that the compensation must vary with the state of the world. Indeed, Fact 6 shows that monetary compensations alone cannot provides incentives for information collection: if $x(R) = 1$ for all $R \in [\underline{R}, \overline{R}] \cup N$, then $r = 0$.

Having established that the third party needs to be a potential entrant, let us turn to the optimal mechanism. In light of the above facts, the regulator's maximization program boils down to

$$\max_{e,r,x(R),x(N)} \sigma(e) + \rho(e) - C(r) - \phi(e)(1+\lambda) +$$

$$r\lambda\left[-z(1-F(R_M,e)) + F(R_M,e)\left(\underline{R} + \int_{\underline{R}}^{R_M} x(R)dR\right) - \int_{\underline{R}}^{R_M} x(R)F(R,e)dR\right] \tag{15}$$

$$+\lambda(1-r)\left[\underline{R} + \int_{\underline{R}}^{\rho(e)} x(R)dR\right]$$

$$s.t. \quad (14)$$

$$0 \leq x(R), x(N) \leq 1$$

$$r[-F_e(R_M,e)(z + \underline{R} + \int_{\underline{R}}^{R_M} x(R)dR) - \int_{R_M}^{\overline{R}} x(R)F_e(R,e)dR] +$$

$$(1-r)x(N)\rho'(e) - \phi'(e) = 0 \tag{16}$$

where the payoff function is given by (4) after having substituted for the optimal reward functions $s(R)$ and $t(R)$ and for $y(R) = 1 - x(R)$, and where the constraint (16) is derived from (13) after the same substitutions.

The following Proposition characterizes the optimal allocation of property rights.

Proposition 2 *At the solution of the optimization program, $x(N) = 1$ and there exists a level of R, denoted with R_p, where $R_p \in [\rho(e), \overline{R})$, such that: for all $R < R_P : x(R) = 1$ and for all $R \geq R_P : x(R) = 0$.*

Recall that in our setting the public authority faces *two moral hazard problems*: one with the incumbent, due to the unobservability of effort in resource maintenance, and one with the entrant, due to the unobservability of information acquisition. Since monetary payoffs cannot be used to induce information gathering from the entrant unless its payoff varies with the state of the world (Proposition 1), the allocation of property rights is *dictated* by the second type of moral hazard. In light of this, expression (14) explains the way property rights can induce monitoring by the entrant. In particular it shows that the incentives to gather information are directly proportional to the probability of gaining property rights when the value of the resource is high ($R > \rho(e)$) and inversely related to the probability of gaining property rights if the value is low ($R < \rho(e)$). This is because from Fact 1 we know that the truth-telling constraint requires that the higher the reported value of the resource the higher the price the entrant must pay. Hence, by giving property rights to the entrant only if it reports good new, the government provides it with incentives to correctly value the asset in order to avoid paying a high price for a low value resource.

Then, *once* the entrant gathers information and truthfully reveals it, monetary payoffs can be used as a compensating differential to discipline the incumbent, in a way described in the Corollary below.

Corollary 1 *There exists a level of R, denoted by R_G, where $R_G \equiv \max\{R_P, R_M\}$, beyond which the incumbent obtains a golden parachute, that is a fixed reward in exchange of its property rights.*

The intuition behind Corollary 2 can be understood by looking at the optimal reward function of the incumbent, in light of Proposition 2, Facts 1, 2 and 3. A priori two cases may arise: 1)$R_M < R_P$, 2) $R_M > R_P$. When $R_M < R_P$,the monetary reward of the incumbent takes the following form

$$\begin{aligned} s(R) &= R & \text{for all } R < R_M \\ s(R) &= -z & \text{for all } R \in (R_M, R_P) \\ s(R) &= -z - R_P & \text{for all } R > R_P \end{aligned}$$

Instead, when $R_M > R_P$,

$$\begin{aligned} s(R) &= R & \text{for all } R < R_P \\ s(R) &= 0 & \text{for all } R \in (R_P, R_M) \\ s(R) &= -z - R_P & \text{for all } R > R_M \end{aligned}$$

Hence, for all $R > R_G \equiv \max\{R_P, R_M\}$, a golden parachute arises: the incumbent obtains a fixed positive reward equal to $(z + R_P)$ in exchange of its property rights and achieves its maximum utility.[6] Notice that the fixed reward is partially financed by the principal and partly by the entrant, since R_P represents the equilibrium price payed by the entrant for the right to use the asset when $R > R_P$. Notice that when $R_M < R_P$, a high positive reward to the incumbent arises even when he retains property rights.

In light of this, we now assess the value of third party monitoring:

Proposition 3 *When $\sigma'(e)$ is high, at the solution of the regulator's optimization program: $\widehat{e} > e^M$.*

[6] Notice that the incumbent's rent is monotonically increasing in R, and it reaches its highest value at $R \geq R_G \equiv \max\{R_P, R_M\}$.

Proposition 3 emphasizes the desirability of introducing competition for the right to exploit a resource. In particular, "auctioning" of property rights can be used as a devise to motivate outside sources to provide the principal with the necessary amount of information to induce incumbent firms to adequately invest. Therefore, when the environmental concern of the regulator is sufficiently vivid ($\sigma'(e)$ is high), the loss in revenues incurred in order to induce environmental protection is justified by the increase in environmental quality: overall expected welfare increases.

At this stage, it may seem natural to ask whether the regulator *needs* to have at his disposal a big amount of funding to devote to environmental policy (our z), for him to be able to induce $\widehat{e} > e^M$. As specified in the corollary below, this is not necessarily the case.

Corollary 2 *Even when $z = 0$, the optimal contract can yield $\widehat{e} > e^M$.*

Clearly, lack of funding limits the power of the incentive mechanism. However, information on the performance of the incumbent can always be valuable to the regulator, since it can be used to increase the sensitivity of the incumbent's payoff to the state of the world. In particular, levels of effort higher than e^M can be achieved by setting $s(R) = R$ for low realizations of R, leaving the agent with a monetary compensation of R_P (payed by the entrant for the right to exploit the resource) in high states ($R \geq R_P$).

4 Conclusions

In our model, the entrant can serve these two roles: a role of information gathering and a role of threat of replacement of the incumbent. Our analysis shows that if there are negative externalities, the entrant is used as a credible threat of expropriation while if there are positive externalities he plays a role of information gathering. In the later case the optimal contract takes a form that generalizes the idea of "golden parachutes."

Literature Review

Most related to our paper are therefore the literatures on second sourcing and on information gathering. 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 (see for example Caillaud, 1990; Demski et *al.*, 1989). However, in the presence of the incumbent moral hazard this positive effect must be balanced with the negative effect on incumbent's incentives (see for example Riordan and Sappington, 1989, Laffont and Tirole, 1998; and Stole, 1994). On the contrary, in our paper, we show that second sourcing may ease the moral hazard problem for it can be used as an information collection device to discipline the incumbent.

Another strand in the literature analyzes the optimal *acquisition of information* by an agent. Typical questions are about the timing of information gathering (Sobel 1993), or the benefit to the principal of having the agent gather information before taking action (Cremer et al. 1998, Lewis and Sappington 1997). Our model departs in a significant way from this literature since information is used to evaluate the *past* performance of *another* agent.

There is a small and recent literature analyzing the effect of golden parachutes on takeovers and the related effect on managerial discipline (Choe 1998, Harris 1990, Knoeber 1990, Shmanske and Khan 1995, Schnitzer 1995). On the one hand, golden parachutes increase the cost of takeovers and increase the bargaining power of the incumbent management. This could lead to excessive deterrence of efficient takeovers or to weaker incentives to fight takeovers. On the other hand, golden parachutes may work as an effective devise to restore ex ante managerial incentives when the threat of rent expropriation, following the possibility of takeovers, exacerbates the under-investment problem. Empirical research tends to suggest a positive effect on stock price due to the provision of golden parachutes (Linn and McConnell 1983, and Knoeber 1990). While some of the intuition from that literature transpires in our model, we depart from it on many grounds. First, we provide a rational for GP arrangements in regulatory settings. Second, we show that GP arrangements are the *optimal state contingent contract* for providing incentives for third party monitoring and for productive effort in a context characterized by double moral hazard and liability constraints. Third, in the above literature GP are designed to make up for the negative effect on incentives of the existence of a third party (the raider). Instead, in our paper, the main rationale for golden parachutes lies in the desirability of inducing third party monitoring.[7]

The optimal contract in our model could be reinterpreted as an option contract: the incumbent has property rights on the asset but the State keeps an option to buy back this right at the beginning of the second period. In (Noldeke and Schmidt 1995) option contracts have been shown to play an important role in alleviating the hold-up problem. Our analysis provides another set of environments, with complete contracts and third party monitoring, in which option contracts are optimal.

Extensions

Since our model is rather stylized, it would be unwise to draw general policy implications. However, we feel that our suggestions might be applied to a variety of settings like renewal of franchising contracts and renewal of maintenance contracts of networks in regulated industries.

Clearly, as in all settings which rely on external auditing to monitor the agent, there may be scope for collusion between the third party and the agent.

[7] In this respect our paper is also related to Holmström-Tirole (1993) who consider a model in which managers have incentives by inducing an *outsider* to collect information and to trade on the basis of this information. Our paper differs from HT in two respects. First, in HT, the firm cannot contract with the outsiders on the amount of information to be acquired and the marginal value of information for the outsiders is linked to (exogenously given and unmodelled) liquidity traders. Instead, we allow for contracting between the principal and the third party and show that the marginal value of information depends on the agreed allocation of property rights. Second, HT highlight the informative role of stock markets as monitors of management while we focus on the informative role of auction-like mechanism and golden parachutes monetary rewards.

However, collusion is not always a problem; its lack of enforceability, the communication costs it involves as well as the threat of being caught and punished can be effective deterring factors. Moreover, by reducing the amount of public funds devoted to induce the right amount of productive effort from the agent, the government can reduce the stake of collusion while at the same time be still able to improve upon private incentives through third party monitoring. In fact in our setting the stake of collusion is increasing in z and, as Corollary 3 suggests, even with $z = 0$ there still may be a role for third party monitoring.

As we have outlined in the introduction, our results have implications for the design of regulations on the allocation of rights of use of the asset. For instance, while periodic auctions are indeed held for the rights to harvest resources, it is not the case that the incumbent receives a payment when the right goes to another party. Our paper suggests that such a simple modification of auctions might improve on dynamic efficiency.

Changes in the assumptions are likely to modify the precise form of the optimal contract but not its "costly option" feature. We consider some directions for future work below.

- Throughout the paper we have assumed that at the beginning of period 2 the incumbent is unable to observe the realized value of R. As is well know if the incumbent and the entrant had correlated information about R the principal would be able to extract this information at lower cost. However, in order to solve the two moral hazard aspects the principal would still need to give rents to the incumbent and to the entrant. In our paper these rents are given by using a particular combination of monetary and property rights; with correlated information, different combinations of these two instruments will be consistent with optimality.

- If agents are risk averse, MLRP still suggests that the incumbent should be given high (utility) payoffs in high states. Since golden parachutes provide full insurance over high outcomes, we conjecture that the optimal contract would still allow for a golden parachute in high states. Moreover, since the value of information for the entrant is higher when it is risk averse (it dislikes more the idea of remaining ignorant), it is likely that R_P increases. The principal will not need to give the entrant property rights as much as before in order to induce information gathering.

- We have restricted the attention to a two-period model. A further extension of our analysis could consider a longer length of the game in order to analyze the evolution of the incentive scheme and allow the entrant itself to submit bids taking into account future auctions. Here the initial problem is complicated by the fact that the incentives for the entrant to exert effort, if it obtains the right to use the asset, are a function of the realized outcome. Monitoring serves now two roles: a "backward" role of monitoring past performance of the incumbent and a "forward" role of predicting the future effect of effort levels.

- For simplicity, throughout the paper we have abstracted from productive efficiency considerations by assuming that the entrant and the incumbent are *ex ante* identical. It is well known that in a world of complete information the most efficient firm should be awarded the right to produce. It is also now well established that the existence of moral hazard problem may induce the regulator to give up bidding parity and favor the firm exerting moral hazard (see for example Laffont and Tirole 1988).[8] If we introduced productive efficiency considerations, bidding parity would indeed not be optimal in our case. However the bias would not be unidirectional but rather dictated by the type of news reported: in favor of the external source whenever good news is reported and in favor of the incumbent in the case of bad news. Similarly, we could extend the analysis to the case where entry involves high sunk costs. Other things equal, sunk costs shift to the right the threshold level (the R_P in our model) above which entry is optimal.

- Another extension of our setting could allow for more than one bidder, in order to establish the link among the number of participants, the individual incentives to gather information and the auction design. Moreover, it would be interesting to analyze the relationship between incentives to acquire information and expected revenues, when the value of the object sold is affected by past users' behavior.[9] This could have relevant implications in circumstances proceeding the privatization of public enterprises.

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A Appendix

Proof of Fact 1. By the Revelation Principle, it is enough to consider truthful equilibria. We can therefore focus on the entrant's revelation problem and obtain the following incentive compatibility conditions. Suppose first that the entrant observes the true state R. Then, letting $U^E\left(R^E;R\right)=y\left(R^E\right)R-t\left(R^E\right)$ denote the payoff (net of sunk costs) of the entrant in the mechanism if he announces state $R^E\in\left[\underline{R},\overline{R}\right]\cup N$, incentive compatibility requires that $U^E\left(R^E;R\right)$ is maximum for $R^E=R$, i.e., that

$$y\left(R\right)R-t\left(R\right)\geq y\left(R^E\right)R-t\left(R^E\right). \tag{A1}$$

For $R^E\in\left[\underline{R},\overline{R}\right]$, standard arguments imply that y, t and $U\left(R\right)\equiv U\left(R;R\right)$ are a.e. differentiable. Moreover, for $R\in\left[\underline{R},\overline{R}\right]$, $y\left(R\right)$ is non-decreasing in R, $t\left(R\right)$ is non-increasing in R and $\dot{U}^E\left(R\right)\equiv y\left(R\right)$. Note that since y is non-decreasing and a.e. differentiable, U^E is a convex function.

If the true state is N (the entrant observes nothing), incentive compatibility takes the form

$$y\left(N\right)\rho\left(e\right)-t\left(N\right)\geq y\left(R\right)\rho\left(e\right)-t\left(R\right), \tag{A2}$$

for $R\in\left[\underline{R},\overline{R}\right]$. From (A1), we also have that for each R,

$$y\left(R\right)R-t\left(R\right)\geq y\left(N\right)R-t\left(N\right) \tag{A3}$$

Since the entrant can run away at any time, the optimal mechanism must also satisfy the interim individual rationality constraint, $U^E\left(R,R\right)\geq 0$ for all R.

Now, consider (A2) and (A3), these can be rewritten as

$$\left[y\left(R\right)-y\left(N\right)\right]R\geq t\left(R\right)-t\left(N\right)\geq\left[y\left(R\right)-y\left(N\right)\right]\rho\left(e\right).$$

Hence, if $R\geq\rho\left(e\right)$, $y\left(R\right)\geq y\left(N\right)$ and $t\left(R\right)\geq t\left(N\right)$, while if $R\leq\rho\left(e\right)$, $y\left(R\right)\leq y\left(N\right)$ and $t\left(R\right)\leq t\left(N\right)$. In particular, at $R=\rho\left(e\right):U^E\left(N\right)=U^E\left(\rho\left(e\right)\right)$.

We can therefore summarize the incentive compatibility conditions by ignoring the transfer t and choosing $y\left(R\right)$ such that $\dot{U}^E\left(R\right)=y\left(R\right)$. Moreover, since the rent is socially costly and non-decreasing in R, the *interim rationality constraint* is satisfied by setting $U\left(\underline{R}\right)=0$. Therefore, integrating $\dot{U}^E\left(R\right)=y\left(R\right)$, we obtain $U^E\left(R\right)=\int_{\underline{R}}^{R}y\left(R\right)dR$ and $U^E\left(N\right)=\int_{\underline{R}}^{\rho(e)}y\left(R\right)dR$, which after integration by parts yields expression (12).

Proof of Fact 2. Suppose that $x(R)+y\left(R\right)<1$ for some R and contract that implements effort levels e and r. Define $\widehat{y}\left(R\right)=y\left(R\right)$, $\hat{t}\left(R\right)=t\left(R\right)$ for each R. Then, the choice of r by the entrant will be the same. Let $\widehat{x}\left(R\right)=1-x\left(R\right)$ and let $\hat{s}\left(R\right)$ be defined by

$$\hat{s}\left(R\right)=s\left(R\right)+\left(\widehat{x}\left(R\right)-x\left(R\right)\right)R.$$

It is immediate that for each R (including state N), the utility of the incumbent is unchanged. Hence, the incumbent also takes the same action e. However, by assumption, the expected payment of the incumbent is larger (since $\widehat{x} > x$), and the government is strictly better off.

Proof of Fact 3. Fixing x and r, the incumbent chooses e that maximizes $EU^I(R, e, r) - \phi(e)$, where $EU^I(R, e, r)$ is given by (3), which yields expression (13).

Proof of Fact 4. Fixing $x(R), e, t$, the optimal $s(R), s(N)$ solves

$$
\begin{aligned}
Max_{s(R),s(N)} \ \int_{\underline{R}}^{\overline{R}} r\lambda s(R)dF(R,e) + (1-r)\lambda s(N) \\
s.t.: \quad (13) \\
s(R) \leq x(R)R \\
s(N) \leq x(N)\rho(e) \\
s(R) \geq -(z + t(R))
\end{aligned}
\tag{A4}
$$

Denoting by β, $\delta(R)$, $\delta(N)$, $\gamma(R)$ the non-negative multipliers of the four constraints above, the first order conditions are

$$
rf(R,e)(\lambda - \beta\frac{f_e(R,e)}{f(R,e)}) - \delta(R) + \gamma(R) = 0 \tag{A5}
$$

$$
(1-r)\lambda - \delta(N) = 0 \tag{A6}
$$

Consider (A5). Since $\frac{f_e(R,e)}{\underline{f}(R,e)}$ is a continuous and strictly increasing function of R, with $\frac{f_e(\underline{R},e)}{f(\underline{R},e)} < 0$, $\frac{f_e(\overline{R},e)}{f(R,e)} > 0$, there exists R^M such that for all $R < R^M$, $-\delta(R) + \gamma(R) < 0$. Thus, $\delta(R) > \gamma(R) \geq 0$ which implies $s(R) = x(R)R$. Instead, for all $R > R^M$, $-\delta(R) + \gamma(R) > 0$, $\gamma(R) > \delta(R) \geq 0$ and $s(R) = -(z + t(R))$. Moreover from (A6), $\delta(N) = (1-r)\lambda > 0$ and $s(N) = x(N)\rho(e)$.

Proof of Fact 5. Since R_M only enters the expected revenue function when R is observed and the incentive compatibility condition of the incumbent (13), the regulator's choice of R_M boils down to

$$
\begin{gathered}
\underset{R_M}{Max}\ r\lambda\left\{-z + F(R_M,e)\left[\underline{R} + z + \int_{\underline{R}}^{R_M} x(R)dR\right] - \int_{\underline{R}}^{R_M} x(R)F(R,e)dR\right\} + \\
(1-r)\,\lambda\,(s\,(N) + t\,(N)) \\
s.t.\ \ r\left\{-F_e(R_M,e)\left[z + \underline{R} + \int_{\underline{R}}^{R_M} x(R)dR\right] - \int_{R_M}^{\overline{R}} x(R)F_e(R,e)dR\right\} + \\
(1-r)x(N)\rho'(e) - \phi'(e) = 0
\end{gathered}
$$

where the payoff function is: $r\lambda\int_{\underline{R}}^{\overline{R}}(s(R) + t(R))dF(R)$, with $s(R)$ and $t(R)$ given by Fact 4, and the constraint is expression (13) evaluated at the optimal $s(R)$ and $t(R)$. The first order condition is $\lambda f(R_M,e) - \beta f_e(R_M,e) = 0$.

Proof of Fact 6. It is obtained by maximizing $EU^E(R,e,r) - C(r)$ w.r.t. r, where $EU^E(R,e,r)$ is given by (12).

Proof of Proposition 1

From the incentive compatibility constraint of the entrant (expression 14) we note that if $x(R) = 1$ for all $R \in [\underline{R}, \overline{R}] \cup N$, then $r = 0$ and the regulator cannot improve upon e^M.

Proof of Proposition 2

Denote by α, $\mu(R)$ and $\nu(R)$ the Lagrangian multipliers of the constraints (14), $x(R) \geq 0$ and $x(R) \leq 1$, respectively and consider Regime 1 ($R_M < \rho(e)$). The first order conditions w.r.t. $x(R)$ are as follows.

For $R < R_M$:[10]

$$r\lambda[F(R_M,e) - F(R,e)] + \lambda(1-r) + \alpha F(R,e) - \beta r F_e(R_M,e) + \mu(R) - \nu(R) = 0$$

For $R_M < R < \rho(e)$:

$$\lambda(1-r) + \alpha F(R,e) - \beta r F_e(R,e) + \mu(R) - \nu(R) = 0$$

For $R > \rho(e)$:

$$-\alpha(1 - F(R,e)) - \beta r F_e(R,e) + \mu(R) - \nu(R) = 0$$

Now, consider Regime 2 ($R_M > \rho(e)$). The first order conditions w.r.t. $x(R)$ are as follows.

For $R < \rho(e)$:

$$r\lambda[F(R_M,e) - F(R,e)] + \lambda(1-r) + \alpha F(R,e) - \beta r F_e(R_M,e) + \mu(R) - \nu(R) = 0$$

For $\rho(e) < R < R_M$:

$$r\lambda[F(R_M,e) - F(R,e)] - \alpha(1 - F(R,e)) - \beta r F_e(R_M,e) + \mu(R) - \nu(R) = 0$$

For $R > R_M$:

$$-\alpha(1 - F(R,e)) - \beta r F_e(R,e) + \mu(R) - \nu(R) = 0$$

Lemma 1 *If a solution exists this implies: (i)* $\beta > 0$; *(ii)* $\alpha > 0$

[10] we have proved (fact 4) that $s(N) = x(N)\rho(e)$ and that (fact 4 again) $t(N) = (1 - x(N))\rho(e) - \int_{\underline{R}}^{\rho(e)}(1 - x(R))dR$. Therefore, $\lambda(1-r)[s(N) + t(N)] = \lambda(1-r)\left[\underline{R} + \int_{\underline{R}}^{\rho(e)} x(R)dR\right]$

Proof of Lemma 1

(i) From the proof of Fact 5 $\lambda f(R_M,e) - \beta f_e(R_M,e) = 0$, and $\beta = \frac{\lambda f(R_M,e)}{f_e(R_M,e)}$. The second order condition in the proof of Fact 5 is: $\lambda[f_R(R_M,e) - \frac{f(R_M,e)}{f_e(R_M,e)} f_{eR}(R_M,e)] \leq 0$. Since $f_e f_R - f f_{eR} < 0$, due to MLRP, then the S.O.C. is satisfied if $f_e(R_M,e) > 0$.

(ii) Suppose by contradiction that $\alpha \leq 0$. From the above first order conditions, in both regimes we have: $\mu(R) - \nu(R) < 0$ for all $R > \rho(e)$. This implies $\nu(R) > \mu(R) \geq 0$ and $x(R) = 1$. But then (14) yields $r = 0$.

In light of Lemma 1, the above first order conditions yield $\nu(R) > \mu(R) \geq 0$ and $x(R) = 1$ for all $R < \rho(e)$. Therefore, for a solution with $r > 0$ to exist, $x(R)$ must be equal to zero for some $R \in [\rho, \overline{R})$ (otherwise the entrant never gathers information). Let R_P be the minimum level of R such that $x(R) = 0$ (i.e., $y(R) = 1$). Since $y(R)$ must be non-decreasing in R, from the proof of Fact 1, then $y(R)$ must be equal to 1 for all $R \geq R_P$. It follows:

(i) In Regime 1: $R_M < \rho(e)$

(i.1) $if: \quad -\alpha(1 - F(\rho,e)) - \beta r F_e(\rho,e) \geq 0$, then $R_P > \rho(e)$

(i.2) $if: \quad -\alpha(1 - F(\rho,e)) - \beta r F_e(\rho,e) < 0$, then $R_P = \rho(e)$

(ii) In Regime 2: $R_M > \rho(e)$:

(ii.1) $if: \quad -\alpha(1 - F(\rho,e)) - \beta r F_e(\rho,e) \leq 0$, then $R_P > R_M$

(ii.2) $if: -\alpha(1 - F(\rho,e)) - \beta r F_e(\rho,e) > 0$, then $R_P \in (\rho(e), R_M)$

Now consider the first order condition with respect to $x(N)$

$$\beta(1-r)\rho'(e) + \mu(N) - \nu(N) = 0$$

where $\mu(N)$ and $\nu(N)$ are the Lagrangian multipliers of the constraint $x(N) \geq 0$ and $x(N) \leq 1$, respectively. In light of Lemma 1, the above condition implies: $\nu(N) > \mu(N) \geq 0$, which yields $x(N) = 1$.

Proof of Corollary 1. It is sufficient to notice that $R_M < R_P$, in Regime 1 and in Regime 2 under condition (ii.2) in the proof of Proposition 2; and $R_M > R_P$ in Regime 2 under condition (ii.1) in the proof of Proposition 2.

Proof of Proposition 3

Consider the case where $C(r)$ is low (close to zero). From Proposition 2 it follows that the principal can induce the entrant to gather information by taking away the resource from the incumbent only for very high realizations of R (neighborhood of $\overline{R}$). In this case, the incumbent's incentive compatibility condition can be approximated by $\rho'(e) - r\int_{\underline{R}}^{\overline{R}} s(R) f_e(R,e) dR = \phi'(e)$. Now, consider a reward function $\widetilde{s}(R)$ that takes value zero till a certain level $\widetilde{R}$ and $-z$ thereafter, where $\widetilde{R}$ is such that $f_e(\widetilde{R},e) > 0$ (and $f_e(R,e) > 0$ for all $R > \widetilde{R}$, by MLRP). Clearly, this reward function could induce an increase in effort with respect to e^M as well as an increase in social welfare when $\sigma'(e)$ is sufficiently high. Since $\widetilde{s}(R)$ is not the optimal reward function, the same if not better can be obtained with a reward function optimally designed.

Proof of Corollary 2

Recall that in the benchmark case with no entrant, the incumbent chooses effort so as to equate $\rho'(e)$ to $\phi'(e)$. Rewrite $\rho'(e)$ as $\int_{\underline{R}}^{\tilde{\tilde{R}}} Rf_e(R,e)dR + \int_{\tilde{\tilde{R}}}^{\overline{R}} Rf_e(R,e)dR$, where $\tilde{\tilde{R}}$ is the level of R below which $f_e(R,e) < 0$ and above which $f_e(R,e) > 0$ (the existence of such $\tilde{\tilde{R}}$ is implied by MLRP), hence $\int_{\underline{R}}^{\tilde{\tilde{R}}} Rf_e(R,e)dR < 0$. It follows that if $s(R) = R$ for all $R < \tilde{\tilde{R}}$, then the level of effort that solves $\int_{\tilde{\tilde{R}}}^{\overline{R}} Rf_e(R,e)dR = \phi'(e)$ is greater than e^M. Now, consider the optimal contract in our setting when $z = 0$, and w.l.o.g. let us focus on the case where the entrant observes the true value of the resource and $R_M < R_P$. Here, $s(R) = R$ for $R \in [\underline{R}, R_M]$, $s(R) = 0$ for $R \in (R_M, R_P]$ and $s(R) = -R_P$ for $R > R_P$. Consequently, the incumbent chooses the level of effort that solves $\int_{R_M}^{R_P} Rf_e(R,e)dR + \int_{R_P}^{\overline{R}} R_P f_e(R,e)dR = \phi'(e)$, where the left hand side term may be higher than $\rho'(e)$.