Decentral Information Acquisition and the Value of Cost Observability

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Abstract

This paper investigates a model where a manager gathers private information about the cost variables of his responsibility center. The owner then elicits the manager's information from a budgeting mechanism. If the manager has to acquire information before the budgeting stage, stronger production distortions relative to the standard adverse-selection situation arise. Moreover, the manager may engage in inefficient rent seeking and overinvests in the acquisition of information. Monitoring the manager's cost of gathering information limits the production distortion. However, this comes at very high rent-seeking activity. Conversely, if the owner commits not to monitor rent seeking is mitigated but at the cost of stronger production distortions.

Key words. Information evaluation, monitoring, endogenous adverse selection, budgeting, incomplete contracts, rent seeking

1 *Introduction*

About three decades ago, the question of the "value of information" (Feltham (1968)) was introduced into mainstream accounting literature and became known as the "information-economics approach" thereafter. Two main problems have been investigated since, namely, (1) should (and if so how) the "information evaluator" evaluate the "decision maker" at his cost, and (2) what type of information system should be provided to the decision maker in order to let him become a decentralized expert. Demski and Feltham (1976) call the first role of information decision influencing and the second decision facilitating.

The present paper investigates aspects of the mutual dependence between both problems. The simple fact that a decision maker (whom I call "manager" henceforth) has been endowed with an accounting information system does by no means imply that he has automatically received all the decision facilitating information he needs. Rather, he first has to incur effort in order to *use* the information system. The effort of eliciting information from the system may be chosen high or low and so may be the informational status of the manager. From the information-acquisition effort, a cost arises. Then, from the perspective of the information evaluator (who is called "owner" hereafter), observing and evaluating the latter cost influences the manager's decision in an interesting way.

In the model, the owner delegates a project-choice decision to the manager. When having successfully gathered information, the manager is privately informed about a project's cost. The owner then sets a budget in order to limit the manager's discretion. Similarly to Antle and Eppen (1985), the budget is biased and some efficient production possibilities are foregone in order to limit the manager's information rent. The first result of the paper is that this efficiency distortion tends to increase if there is a possibility that the manager did not use the information system successfully and therefore may be poorly informed about the net value of the project.

The second issue of the paper concerns the owner's *ex-ante* decision of whether to commit to monitor the manager's cost of information acquisition and subsequently use the obtained signal when determining the manager's budget. The volume of that cost gives the owner a hint of "how deep" the manager's expertise is or, more technically, how serious asymmetric information about the manager's type is. That knowledge, on the one hand, may be beneficial to the firm because budgets can be adjusted specifically to the operational decisions to be taken by the manager. On the other hand however, the ability of setting well balanced budgets may also have *ex-ante* implications on the manager's incentives for thorough use of the information system in order to properly gather decision-relevant information. The latter effect arises because balancing the manager's budgets influences managerial "slack" and hence part of the manager's implicit compensation.

The main result of the paper is that there may easily arise too strong managerial incentives to collect information. Thus, the manager tends to overuse the information system and inefficient rent seeking occurs. On the other hand, as mentioned before, there is serious underproduction. It follows that in many cases the value of cost monitoring depends on an interesting tradeoff between the manager's activity to gather information and the owner's incentives to set efficient budgets. It is shown that monitoring serves to limit the production distortion. However, this comes at the cost of very strong rent-seeking activity by the manager. Conversely, rent seeking is mitigated if the owner commits not to monitor the manager, but now at the cost of stronger production distortions.

The literature has often assumed that the information system is either provided to and *perfectly used* by the manager or not provided at all (Baiman and Demski (1980) section 3, Baiman and Evans III (1983), Penno (1984), Baiman and Sivaramakrishnan (1991)). In my paper, the agent may be informed or, because of his unsuccessful use of the information system, he may be uninformed. Thus, there is only *imperfect use* of the information system and the owner faces the difficulty of setting budgets for a possibly ignorant manager.[1] This part of the problem has been investigated recently in the economics literature. Lewis and Sappington (1993) assume that an agent may be ignorant with a certain exogenously given probability. However, they do not investigate the agent's incentives to gather information. The latter point is addressed in Crémer and Khalil (1994) and Kessler (1995) but these two papers only describe the case of two states of nature. In contrast, my paper assumes an infinite number of possible states and, more importantly, comes to different results.[2]

[1]Imperfect use of an information system is an issue in Antle and Fellingham (1995). They investigate a model where the manager perfectly and the owner imperfectly uses the information system.

[2]Independently of my work, Crémer, Khalil and Rochet (1996) have investigated the Nash equilibria of a more general endogenous adverse-selection model. The main difference lies in their assumption that the agent either learns his type prior to the contracting stage or *prior* to the production stage. Contrary, in my model, the agent learns the type prior to the contracting stage or *after* the production stage. Hence, my paper allows for socially beneficial information acquisition (with information there is a possibility to efficiently adjust production) whereas in Crémer et al. (1996) the too early and costly gathering of information is always wasteful. Related work has also been done by Lewis and Sappington (1997) and Crémer, Khalil and Rochet (1997) who investigate how to set incentives for the manager's information-acquisition activity.

The paper is also related to Demski and Sappington (1987). However, in that paper it is assumed that the productive act imposes no personal cost on the manager. There is also a relationship to work by Conroy and Hughes (1987). There, the manager gathers information and the owner makes the production decision whereas in my paper the manager takes both actions. Balakrishnan (1991) investigates the impact of postcontractual information acquisition by the manager to the resource allocation decision. In my model, information acquisition occurs before the owner sets the budget, i.e. (in Balakrishnan's language), I assume pre"contractual" information search.

There is also a link to the literature on the hold-up problem (Tirole (1986), Rogerson (1992)). The analogy applies because the manager "invests" into his informational status before receiving the budget announcement. Monitoring makes this "investment" observable. Thus, the value of monitoring can be evaluated by comparing a model of observable investment to one of unobservable "investment."[3] Related to the latter point, Sundem (1979) very early made the point that altering the underlying game tree of the model or — in other words — the information evaluator's information set induces changes in the decision maker's allocation decision.

The remainder of the paper is organized as follows. The next section introduces the model. Then, section 3 investigates the optimal budget set

[3]To this respect, my paper draws from the "renegotiation proofness" idea introduced by Dewatripont (1988) and thereafter investigated for several problems like vertical integration (Riordan (1990)), privatization (Schmidt (1996)) or "arm's length relationships" (Crémer (1995)).

by the owner as a response to any given managerial effort level to gather information. Afterwards, sections 4 and 5 describe the respective equilibria of the games without and with monitoring. Section 6 generalizes the analysis and allows for stochastic monitoring. Finally, section 7 concludes.

2 *The Model*

Consider a firm which is organized as a two-level hierarchy. The top layer may be thought of as the owner. She sets up a discretionary expense-center organization and employs a manager who is responsible to run the firm's business.[4] It consists of several old projects. Moreover, there is one new project to be introduced including the production of a fixed quantity q which is normalized to one. The owner assesses an incremental valuation of v to the new project. v is assumed to be exogenously given and commonly known. Let the incremental cost of the new project be c. It is common knowledge that c is distributed over an inverval $[\underline{c}, \overline{c}]$ following a distribution function F with positive density f. Assume that F satisfies a usual regularity condition, i.e., that the inverse hazard rate, $F(c)/f(c)$, increases in c. When coming to the comparative statics of the model, I shall consider a range of valuations within in interval $[\underline{v}, \overline{v}] = [\underline{c}, \overline{c} + \frac{1}{f(\overline{c})}]$.[5]

[4]Kaplan and Atkinson (1989), 531-533, recommend discretionary expense centers for units which produce an output not measurable in financial terms or for units where a precise relationship between inputs and outputs cannot be specified.

[5]For $v < \underline{v}$ there would be no trade and for $v > \overline{v}$ the analysis below will reveal that the outcome is first best. Thus, valuations outside of $[\underline{v}, \overline{v}]$ are of little interest.

At the first stage of the game, c is unknown to both, the owner and the manager. However, the manager can spend a cost $k(p)$ out of the expense center's accounts in order to realize a probability p according to which he learns the true cost parameter c. Hence, with probability p the manager will be informed at the second stage and continuation play will proceed under adverse selection. With probability $(1-p)$ the manager stays uninformed and the game continues under symmetric (non)information. Assume that $k(0) = k'(0) = 0$, and $k(p > 0) > 0$, $k'(p > 0) > 0$, $k''(p) > 0$, $\lim_{p \to 1} k(p) = \infty$.

The manager receives an expenditure authorization in form of a budget of volume b in order to realize the project. As the true cost c is unobservable to the owner, there may arise managerial slack in the form of an excess budget $(b-c)$. The latter can be diverted into "perks" by the manager and consumed by himself.[6] Thus, the manager's ex post rent is given by

$$(b-c)q \qquad q \in \{0,1\}.$$

So far, no participation of the manager in the budgeting process is assumed. From an a priori modeling perspective, this may be restrictive. However, I demonstrate further below (corollary 1) that the restriction imposed by the no-participation assumption is not binding in my model. Thus, the top-down budgeting procedure is sufficient to guarantee an optimal outcome from the owner's perspective.

[6]See Antle and Fellingham (1995), and Mookherjee and Reichelstein (1996).

Assume that the manager has a quasi-linear utility function. A particular realization of the monetary value of his stage-one utility can be written as:

$$w + (b - c)q - k(p) \qquad q \in \{0, 1\}$$

where w is a lump sum payment to ensure participation of the manager.

The owner's utility is

$$(v - b)q - w \qquad q \in \{0, 1\}.$$

Finally, assume for simplicity that the manager faces no binding wealth constraint at the time of the production decision. The idea is that he formerly has built up some slack S from the other projects. To keep the subsequent analysis simple assume that S is "high" such that the manager's department can pay any loss that might arise if an uninformed manager accepts a budget and an unfavorable state of nature is realized.[7]

The timing of the game is as follows. At the beginning the owner acquires the possibility to introduce the new product and decides upon the installation of a monitor for realized cost of information acquisition, k^r. She then updates the managerial compensation contract subject to the manager's participation constraint. After having signed the new contract, the manager

[7] This assumption avoids that bancrupcy of the manager's department becomes an issue. However, it would be interesting to investigate the consequences of limited managerial *ex-post* liability in future research. The condition for the no-bancrupcy assumption to hold is that, in equilibrium, S exceeds $\overline{c} - E(c)$ plus the expected managerial information rent in the case the information-state of nature.

uses the accounting information system in order to elicit information about production costs c. In doing so, he spends the cost $k(p)$ and then learns c with probability p. Afterwards, depending on the installation of the monitor, the owner either observes $k(p)$ or not. In the first case, she can infer the probability p whereas in the latter she cannot. Conditional on the monitoring result, the owner sets the budget b.[8] Given b, the manager decides upon production or nonproduction. Finally, all payoffs are realized. Before analyzing the game, consider the three key assumptions of the model more closely.

Incomplete Contracting. All cost and revenue informations are assumed to be uncontractible. This assumption is based on the notion of verifiability of information to third parties (see e.g. Hart (1995)). As has been pointed out in the incomplete contracting literature, it only makes sense to incorporate a particular information into a compensation contract if it is verifiable to a third party. Verifiability is needed to enforce the content of the contract if it comes to a dispute. If there is no possibility of its enforcement, a contract is worthless since the parties can always cheat at the specified obligations without punishment. However, a third party like a court usually will have information of lower quality than the two contracting parties. In particular, the third party is assumed not to be able to verify the allocation of indirect costs to either c, k or any other cost variable, the latter being outside the

[8]The assumption is that there is no possibility for the owner to commit to some standardized budget $\overline{b}$ before $k(p)$ is determined.

model. In other words, a cost observation is only "soft" information. The incomplete-contracting assumption implies that the only compensation which can be agreed upon at the contracting stage is a lump-sum wage payment w. Notice however, that the players implicitly agree on a richer contract. Through the optimal budgeting mechanism the owner can elicit information about c. Moreover, the manager earns rents additional to his lump-sum wage which, in equilibrium, are contingent on his information gathered about c.

No Commitment. There is no possibility for the owner to commit to a budget at earlier stages of the game. Of course, that possibility could mitigate the arising incentive problems.[9] However, that would require the manager to have *veto* power against *ex-post* changes of the budget, i.e., the two actors would have to write a binding *contract* over the budget. Possibly in order of not disclosing strategically important cost information to outsiders, this is unrealistic for budgetary procedures. Therefore, the manager has no legal right to enforce a budget that has been promised to him at an early time point. Rather, the owner can, at any time, alter the amount of the budget. Thus, the only binding announcement can be made immediately before production takes place.

Monitoring. *Ex ante* the owner commits to a technology of *ex-post* cost monitoring. Because of the uncontractibility of cost information observing

[9] For the symmetric *ex-post* information case, see e.g. Edlin and Reichelstein (1996) and the references therein.

the realization of c is of no value since there is no action of the owner after production has been completed. However, this is different for the observation of $k(p)$. That observation occurs before the owner sets the budget b. Monitoring $k(p)$ enables the owner to infer the probability p according to which the manager is informed about the true value of c. The knowledge about p will alter the owner's behaviour and therefore have efficiency consequences.

3 *The Owner's Problem*

In this section, I investigate the owner's best-response pattern to any *given* probability that the manager is informed. I will develop the results slowly and first outline the polar cases where (1) the manager did not use the information system and therefore is uninformed about c ($p = 0$) and (2) the manager costlessly and fully uses the information system ($p = 1$). This is done in subsection 3.1. The general case of $p \in (0, 1)$ follows in subsection 3.2.

3.1 Polar Cases

The manager is uninformed. Suppose the manager is uninformed about c because he did not use the information system at all. His risk neutrality and sufficient liability then imply that he will accept a budget b if and only if $b \geq E(c)$. In that case he realizes the project. Contrary, for $b < E(c)$ budget and project are rejected.

Given this behavior, the owner sets a budget of $b = E(c)$, if her valuation v exceeds $E(c)$. If the valuation is less than $E(c)$ the owner sets a lower budget (e.g. $b = \underline{c}$). Notice the role of the manager's full *ex-post* liability. Once the project is accepted, the manager's department must (and is assumed to be able) to pay the true cost c even if $c > b$.

The manager is informed. Now consider the opposite case where information acquisition is costless and therefore the manager infers the true value of c with probability $p = 1$. This is the standard adverse selection situation. Given any budget b, all cost types $c \leq b$ will realize the project. From the viewpoint of the owner, this happens with probability $F(b)$. When setting the budget the owner therefore maximizes

$$(v - b)F(b).$$

This leads to the profit-maximization condition of

$$b = v - \frac{F(b)}{f(b)}. \tag{1}$$

(1) is the well-known optimality condition for situations with adverse selection. The first-best efficient budget would be set at $b = v$ because then it would be guaranteed that all types $c \leq v$ would realize the project. However, that strategy would also maximize managerial perquisites. In fact, all the surplus available would fall to the manager. In order to limit slack, the

owner depresses b below its first-best level forgiving some production opportunities but also lowering the manager's expected rent. Notice that the optimal budget $\hat{b}$ leaves a manager of type c an information rent of

$$\hat{b} - c = v - c - \frac{F(\hat{b})}{f(\hat{b})}.$$

Thus, compared to the first-best efficient budgeting rule the rent has been reduced by $F(\hat{b})/f(\hat{b})$. For what follows, it will be important to notice that the magnitude of budget reduction critically depends on the probability mass of types smaller than $\hat{b}$, $F(\hat{b})$. If (everything else equal) that mass increases the owner responds with a sharper cut of the budget.

3.2 The General Case

Now consider the general case where the manager is informed about c with a probability p strictly between zero and one. With probability $(1-p)$ he is uninformed. Following the analysis of the previous subsection, the owner's expected ex post rent $E(R_O)$ changes to:

$$E(R_O) = \begin{cases} p(v-b)F(b) + (1-p)(v-b) & \text{if } b \geq E(c) \\ p(v-b)F(b) & \text{if } b < E(c). \end{cases} \tag{2}$$

This function is maximized with respect to the budget proposal b. The outcome of this optimization problem is summarized in proposition 1 below which is consistent with the results of Lewis and Sappington (1993).

PROPOSITION 1 *Depending on the owner's valuation, three cases for the optimal budget proposal can be distinguished.*

- **Case 1 ("Low" valuation of the project):** *Suppose the owner's valuation for the project is low, i.e.* $v \leq v^* = E(c) + \frac{F(E(c))}{f(E(c))}$. *In this case the optimal budget follows from the classic adverse-selection optimality condition:*

$$b = v - \frac{F(b)}{f(b)}. \tag{3}$$

- **Case 2 ("High" valuation of the project):** *Suppose now the owner's, valuation for the project is high, i.e.* $v^* < v \leq v^{**}(p)$ *where, for any given probability* p, $v^{**}(p)$ *is given by* $v^{**}(p) = E(c) + \frac{F(E(c))}{f(E(c))} + \frac{1-p}{p \cdot f(E(c))}$. *Then, the optimal budget is given by*

$$b = E(c).$$

- **Case 3 ("Very high" valuation of the project):** *For a given* p *suppose that* $v > v^{**}(p)$. *In the third case the optimal budget follows from:*

$$b = v - \frac{F(b)}{f(b)} - \frac{1-p}{p \cdot f(b)}. \tag{4}$$

Proof. All proofs are in the appendix.

The cases of "high" and "very high" valuations ($v > v^*$) are of special interest since then the optimal budget deviates from the standard adverse selection case, namely, $p = 1$. Suppose, the manager is ignorant at the budgeting stage. Then, he behaves as if he was of type $E(c)$. Hence, technically spoken, the introduction of a positive probability $(1 - p)$ that the manager is uninformed changes the distribution function of c relative to the adverse selection case ($p = 1$) by introducing a mass point at $E(c)$. Now, consider the case of positive production for any type $c > E(c)$. Then, the budget b exceeds $E(c)$ since otherwise a manager of type $c > E(c)$ would reject to produce. Hence, in comparison to the standard model (i.e. $p = 1$), the optimal contract must provide additional information rents for the now strictly positive mass of uninformed types, i.e. those cost types at $c = E(c)$. In order to limit those rents there is an output distortion for types higher than $E(c)$ which exceeds that of the standard model. As a consequence, the owner shuts down cost types higher than $E(c)$ more likely than in the standard model. Notice that for a "low" valuation ($v \leq v^*$) this incentive is not binding for any p. Then, the owner's valuation is too low to take production for any type $c \leq E(c)$ into account. Thus, no information rent to uninformed types must be payed.

Consider the cases 2 and 3 more closely. For budgets above $E(c)$, virtual cost in the endogenous adverse selection ($p \in (0,1)$) model is higher than in the standard adverse-selection model (where $p = 1$). Notice that, by (4), the additional virtual cost under endogenous adverse selection tends to infinity for very small p. Therefore, for any $v > v^*$, there exists a critical probability p^* such that for $p \leq p^*$ production is not extended to types beyond $E(c)$. In those cases, the optimal budget equals $E(c)$. Contrary, for $p > p^*$, the extra virtual cost becomes sufficiently low such that production is extended beyond $E(c)$. Then, condition (4) describes an interior solution. In the latter case, the optimal budget exceeds $E(c)$ and increases in p:

$$\frac{\partial b(p|v > v^{**})}{\partial p} = -\frac{f(b)(v-b) + 1 - F(b)}{\partial^2 E(R_O)/\partial b^2} > 0. \tag{5}$$

From (4), notice also that the extra virtual cost vanishes if $p = 1$ in which case we are back to the standard adverse-selection model.

To summarize, for high valuations $v > v^*$ the owner's reaction schedule consists of two parts. For $p \leq p^*$ the optimal response is to set a budget $b = E(c)$, independently of p. As p increases beyond p^*, the optimal budget is increasing in p. For $p = 1$ the optimal budget is equal to the one in the standard model.

This top-down budgeting rule does not require any participation of the manager. Contrary, there is a common theme in the literature that optimal budgeting mechanisms should invoke participation of the manager.[10] Such participation may be twofold. First, there may be direct communication of c from the manager to the owner. Then, the budgeting mechanism provides an allocation contingent on the manager's report. This contingency is balanced in a way that truthful reporting applies in equilibrium. Second, communication may be indirect. Then, the mechanism provides a menu of allocations. The manager is required to pick one particular allocation out of this menu. The manager indirectly reveals his private information by choosing an allocation. Corollary 1 states that there is no loss for the owner in restricting

[10]See Christensen (1982), Baiman and Evans III (1983), Penno (1984), Kirby, Reichelstein, Sen and Paik (1991), Kanodia (1993), and Mookherjee and Reichelstein (1996).

the form of the budgeting rule to the case of no participation.

COROLLARY 1 *Compared to participative budgeting there does not arise any extra cost for the owner by restricting the budgeting mechanism to the above top-down procedure.*

The result of corollary 1 critically hinges upon the specification of the model and deserves some explanation. Consider a participative budgeting mechanism, where the manager is supposed to report c. According to the revelation principle, there must be incentives for truthful reporting. A well known result from the mechanism design literature is that for truthful revelation of c the quantity $q(c)$ must be decreasing in c. However, as the quantity is either equal to one or to zero, there must be some critical value $\tilde{c}$ such that for all $c \leq \tilde{c}$ the project is realized and for all $c > \tilde{c}$ it is not. Then, all types are pooled within two groups, being *indifferent* to report any type within their respective cost interval. Put differently, the owner can only be sure about the truthfulness of the cost report for the critical types around $\tilde{c}$. However, the same quality of information is generated by the above top-down mechanism. From observing acceptance or rejection of a proposed budget b the owner can infer whether the manager's type is below or above $\tilde{c}$. Therefore, the optimization over $\tilde{c}$ in a revelation mechanism is equivalent to the optimization over b. Hence, in the special model developed in this paper, top-down budgeting delivers the same allocation as participative budgeting. The upper efficiency bound for the firm is therefore attained.

4 *No Cost Monitoring: Low Production and low Rent Seeking*

This section assumes that the owner has decided not to evaluate the cost $k(p)$. Therefore, she cannot infer the chosen probability p before setting the budget b. Hence, the budget proposal described in section 3 is a Cournot-Nash response to an anticipated equilibrium value, $\hat{p}$. To find the equilibrium, I now seek the manager's best response to any given budget b. At the time of choosing the probability p, the manager's expected payoff can be written as

$$p \cdot \int_{\underline{c}}^{b} (b-c)f(c)dc - k(p) + (1-p) \cdot \begin{cases} 0 & \text{if } b < E(c) \\ (b - E(c)) & \text{if } b \geq E(c). \end{cases} \tag{6}$$

The last part of (6) reflects his expected incremental utility if he remains uninformed. Then, he will reject any budget below the expected cost $E(c)$. Hence, in that state of nature he is guaranteed to receive a nonnegative expected rent which is equal to the maximum of zero and $(b - E(c))$. The first part of the sum is his expected rent if he is informed about c. Then, he will realize the project whenever b exceeds c. I now state the properties of the manager's best-response schedule:

LEMMA 1 *Without monitoring, the manager's best response to $b = \underline{c}$ is $p(\underline{c}) = 0$. For $\underline{c} < b < E(c)$ the manager's best response function is increasing in b whereas for $E(c) < b < \overline{c}$ it is decreasing. For $b = \overline{c}$ the*

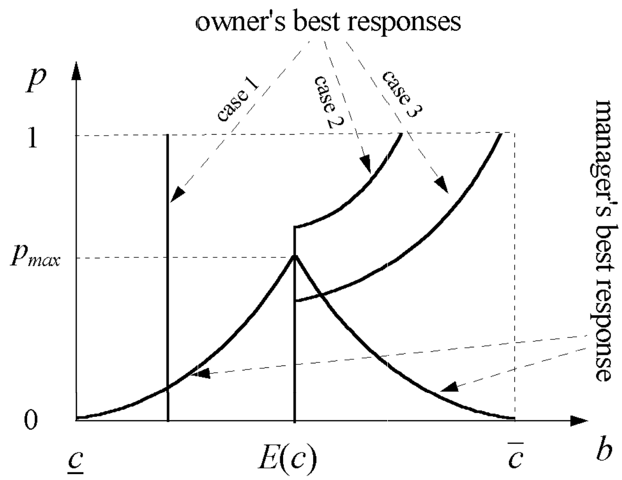

Figure 1: Alternative Nash Equilibria without Cost Monitoring

best response $p(\overline{c})$ *equals zero again. Finally, the best response function is piecewise convex for all* b.

Figure 1 shows the shape of the manager's "reaction" curve and three possible cases for the owner's best response schedule. Consider the manager's decision, namely $p(b)$, first. The shape of the manager's "reaction" curve shows that his incentives to acquire information are highest for an intermediate budget $b = E(c)$. Moreover, for extreme budgets $b = \overline{c}$ and $b = \underline{c}$ incentives vanish and the manager will choose $p = 0$. The reason is simple: For $b = \underline{c}$, the probability of realizing the project is zero and hence there is no incentive for the manager to gather any information which might guarantee him some rents. For growing b, there are two incentive effects. First, the manager must take into account how the expected information rent changes if he stays uninformed. In that case, as long as $b < E(c)$, he will reject the project and earn no rents. Hence, for $b < E(c)$ the first effect is zero.

Second, the manager might successfully gather information about c. Then, he accepts the project conditional on $c \leq b$. For growing b this becomes more and more likely. Therefore, within the interval $(\underline{c}, E(c))$ the manager's expected information rent, $b - E(c|c \leq b)$, is positive and grows in b. Thus, the best-response function is increasing in b. As b approaches $E(c)$, the mass of uninformed types will also accept the project. Now, for further growing b incentives to gather information about the true cost type change. Concerning the first incentive effect, the manager now gathers an expected rent in the no-information state of nature. However, this becomes more and more unlikely when p is raised. Hence, now the first incentive effect is negative. Contrary, the second effect is still positive. Taking the net of both effects, for any $b < \overline{c}$ the marginal gain of the expected rent $[b - E(c|c \leq b)]$ in the information state exceeds the marginal expected loss in the no-information state, $(b - E(c))$. Thus, there is a positive net incentive to gather cost information. However, the net incentive is decreasing in b. At $b = \overline{c}$ the extra advantage has vanished. Then, the manager's expected type conditional on acceptance of the project in the informed case, $E(c|c \leq b = \overline{c})$, equals $E(c)$.

Moreover, figure 1 depicts the three possible best-response functions of the owner and hence three possible types of equilibria. Consider case 1 where v is "low". Then, by condition (3) of proposition 1, the owner's reaction curve is independent of p and the optimal budget is lower than $E(c)$. Further, for $v \geq v^*$, two cases can occur. First, it may be that at $p_{max} \equiv p(E(c))$ the owner's best-response may be independent of p. Then, the equilibrium is given by $(\hat{b} = E(c), \hat{p} = p_{max})$. Notice that this equilibrium occurs for all $v^* \leq v \leq v^{**}(p_{max})$. The equilibrium for $v > v^{**}(p_{max})$ is more interesting. Then, at p_{max} the owner's best response function is increasing in p. Therefore, the intersection point of the two best-response functions gives the equilibrium $(\hat{b} > E(c), \hat{p} < p_{max})$. This is summarized by the following proposition which is stated without proof.

PROPOSITION 2 *Define p_{max} as being given through $k'(p_{max}) = E(c) - E(c|c \leq E(c))$. Without monitoring there are three possible equilibrium regimes.*

- **Case 1 ("Low" valuation of the project, $v < v^*$):** *The equilibrium is given by $\hat{b} < E(c)$ and $\hat{p} < p_{max}$.*
- **Case 2 ("High" valuation of the project, $v^* \leq v \leq v^{**}(p_{max})$):** *The equilibrium is given by $\hat{b} = E(c)$ and $\hat{p} = p_{max}$.*
- **Case 3 ("Very high" valuation of the project, $v > v^{**}(p_{max})$):** *The equilibrium budget $\hat{b}$ exceeds $E(c)$ and the equilibrium probability $\hat{p}$ is lower that p_{max}.*

It is of further interest to consider the efficiency of the derived no-monitoring equilibrium. As is well known from the standard adverse-selection model ($p = 1$), the budget b is lower under adverse selection that in an ideal world of full information. Therefore, under adverse selection the output is produced in less states of nature than in the first-best world. Section 3 has shown that this quantity distortion tends to be even more serious in the endogenous adverse-selection model. Given this budget distortion, consider now the implemented probability of information acquisition. To judge efficiency of the latter, the reference point is taken from a world in which the manager commits to the maximization of the social gains given the budgeting behaviour of the owner. The efficient probability level p^{eff} therefore maximizes

$$p \cdot \int_{\underline{c}}^{b} (v-c) f(c) dc - k(p) + (1-p) \begin{cases} [v - E(c)] & \text{if } b \geq E(c) \\ 0 & \text{if } b < E(c). \end{cases} \tag{7}$$

Comparison to the manager's decision rule in the model leads to the following proposition.

PROPOSITION 3 *Without monitoring the manager*

- *under"invests" in p if $v < v^*$ and hence $b < E(c)$*
- *over"invests" in p if $v \geq v^*$ and hence $b \geq E(c)$.*

Proposition 3 reveals the welfare consequences of endogenous adverse selection. First, consider the case of a "low" valuation $v < v^*$. Then, a classic *hold-up problem* arises and the manager under"invests" in p. If $v < v^*$, it is a dominant strategy for the owner to set a budget $b < E(c)$, irrespectively of p. Therefore, an uninformed type of manager will reject production. However, this implies that the only possibility to receive a private gain from production of the new product comes from the manager's activity to raise the probability of learning the true value of c. As there is a positive probability that $c < b$, there is a positive expected rent prior to learning c which gives the manager an incentive to incur a cost $k(p)$. However, since the owner sets a budget strictly below her valuation v, the manager's private gain from raising p is lower than the social return. This implies that the efficient probability, p^{eff}, exceeds the equilibrium probability $\hat{p}$. Notice that the problem arises solely because of the distorted budget. If the owner would use a socially efficient budgeting rule, i.e. $b = v$, the distortion in p would vanish (Tirole (1986)).

Now, consider the case of a high valuation, $v > v^*$. As mentioned above, the manager's incentives to gather information now are twofold. On the one hand, the under"investment" effect just described is still present. However, now there is an additional incentive effect pointing into the reverse direction. When raising p under the efficient budgeting rule ($b = v$) the manager raises the probability of loosing the expected rent $[v - E(c)]$ in the non-information state of nature whereas the respective marginal loss is only $[b - E(c)]$ under inefficient budgeting. This implies that with inefficient budgeting the manager has more incentives to "invest" in p than with efficient budgeting. Hence, the manager is now faced with *rent-seeking incentives*. It turns out that the rent-seeking effect dominates the hold-up effect: This is because an informed manager accepts conditional on $c \leq b$ whereas in cases 2 and 3 ("high" valuation and hence $b \geq E(c)$) an uninformed manager accepts with probability one. Therefore, the hold-up effect has only weight $F(b) < 1$ and the rent-seeking effect has weight one. Summing up, contrary to the case of low valuation, there is too strong information-acquisition activity for $v \geq v^*$.

5 *Cost Monitoring: High Production and High Rent Seeking*

Suppose now the owner decides to monitor the realized information acquisition cost $k^r = k(p)$. Then, from that observation she can infer the underlying probability $p = k^{-1}(k^r)$. Therefore, when setting a budget b, she reacts to the true value of p instead of an anticipated Nash equilibrium probability $\hat{p}$. Hence, technically spoken, the budget will be a function of p. Thus, additionally to the previous section, when changing p the manager will take a strategic effect into account. Now, a change of p may alter the owner's proposed budget b (see proposition 1). Lemma 2 below investigates the magnitude of the strategic effect.

LEMMA 2 *The size of the additional strategic effect for choosing p under cost monitoring differs in the three subsequent cases:*

- **Case 1 ("Low" valuation for the project, $v < v^*$):** *The owner's best response is given by $b = v - \frac{F(b)}{f(b)}$ and independent of p. Thus, the strategic effect is zero.*
- **Case 2 ("High" valuation for the project, $v^* \leq v \leq v^{**}(p_{max})$):** *Here $b = E(c)$, independently of p. As before, there is no strategic effect.*
- **Case 3 ("Very high" valuation for the project, $v > v^{**}(p_{max})$):** *Now, there is a positive strategic effect, resulting from equation (5) above, namely*

$$\frac{\partial b(p|v > v^{**})}{\partial p} = -\frac{f(b)(v-b) + 1 - F(b)}{\partial^2 E(R_O)/\partial b^2} > 0.$$

Lemma 2 tells that the equilibrium value with monitoring, $\tilde{p}$, does not differ from the no-monitoring equilibrium value $\hat{p}$ in the first two cases. Therefore, in what follows, I restrict attention to "very high" valuations.

PROPOSITION 4 *For a "very high" valuation $v > v^{**}(p_{max})$ the equilibrium value $\tilde{p}$ with monitoring exceeds the corresponding $\hat{p}$ without monitoring. Moreover, the budget with monitoring $\tilde{b}$ exceeds the no-monitoring budget $\hat{b}$.*

Proposition 4 tells that if production is extremely important from the perspective of the owner she will increase b relative to the case of unobservability. The reasoning is as follows. When (indirectly) observing $p = k^{-1}(k^r)$, the owner can infer the actual magnitude of the mass of uninformed types. As for "very high" valuations, b exceeds $E(c)$ anyway, an increase in p tells the owner that there is a decrease of the expected extra virtual cost which has to be provided to the mass of uninformed types relative to the standard model. Thus, she will partially give up her inefficient budgeting behaviour and raise b relative to the case of cost unobservability.

This increase in b will be anticipated by the manager when the deciding about p. As for any $b > E(c)$ the budget increases in p, he will earn an extra rent from the triggered increase in b in both, the information and the non-information state of nature. Thus, there is a gain for the manager in raising p above the no-monitoring level $\hat{p}$.

However, the efficiency gain with respect to production also comes at a cost. Due to increased rent-seeking activity, the manager even increases his over-acquisition of information. This result formally proves an intuition which has been stated first in the concluding section of Lewis and Sappington (1993). From the observation that the manager earns lower *ex-post* rents under endogenous rather than under exogenous adverse selection it follows that he will be interested in credibly signalling that he is informed about c. If there is monitoring, p becomes de facto observable. Thus, it pays for the agent to demonstrate that he is informed with "high" probability. Therefore, the manager increases $\tilde{p}$ beyond its respective level $\hat{p}$. Then, he biases the owner's budget closer towards the budget which would apply under exogenous adverse selection (where $p = 1$).[11]

6 *Closer Description of the Tradeoff and Example*

The owner's basic tradeoff when deciding whether to monitor the cost realization $k(p)$ now can be summarized. Unobservability of $k(p)$ induces the manager to engage in inefficient rent-seeking behaviour which ultimately affects the owner as she has to compensate the manager at the contracting

[11]Interestingly, the overinvestment result may possibly hinge upon the number of possible states of nature and their probability distribution. Kessler (1995) analyzes a similar model with only two states. In her paper, a "value of ignorance" arises. The reason is in her model the uninformed type is pooled with the low-cost type if p is high. Then, the uninformed manager receives no information rent. To avoid this, p is bounded away from 1 even if raising p is costless at the margin.

stage for his anticipated utility loss $k(p)$. On the other hand, observing p makes it possible for the owner to assess the true mass of uninformed types which, according to the manager's overly strong rent-seeking behaviour, is quite low. Hence, the owner partially can give up the restrictive budgeting rules which she commits to without monitoring. Thus, there is also a beneficial effect from observing $k(p)$.

Conversely, no monitoring commits the owner to a more inefficient budgeting rule which incurs a cost to the owner because of the foregone output. However, the beneficial effect from unobservability of $k(p)$ is that rent seeking incentives are depressed relative to the case with monitoring.

However, in real life the monitoring frequency rarely will take the extreme values of "ever or never" as investigated so far. The purpose of this section is to introduce a monitoring probability, α, and to investigate the quality of the tradeoff more closely. Therefore, suppose that at the stage of the monitoring decision the owner may commit to a mixed monitoring strategy.

By lemma 2, monitoring only has value if the owner's incremental valuation v exceeds the critical value of $v^{**}(p_{max})$. Therefore, this section restricts attention to those cases. Call b^{+} the owner's best response schedule to an observed value of p and b^{-} her Nash-reply budget without monitoring. At the time of choosing p the manager's expected payoff is

$$\alpha\left[p\int_{\underline{c}}^{b^+(p)}(b^+(p)-c)f(c)dc-k(p)+(1-p)\cdot(b^+(p)-E(c))\right]$$
$$(1-\alpha)\left[p\int_{\underline{c}}^{b^-}(b^- -c)f(c)dc-k(p)+(1-p)\cdot(b^- -E(c))\right] \qquad (8)$$

The manager's choice of p maximizes this expression. Then, the owner selects a budget contingent on her observation or nonobservation of p. The analysis starts with the following lemma.

LEMMA 3 *Suppose $v > v^{**}(p_{max})$. Then, the following two statements hold:*

1. *In equilibrium, the budgets b^+ and b^- coincide: $b^+ = b^- \equiv b(\alpha)$.*
2. *For any monitoring probability $\alpha \in [0,1]$ the equilibrium $[b(\alpha), p(\alpha)]$ follows from the two Nash-reply schedules:*

$$b(\alpha)=v-\frac{F(b(\alpha))}{f(b(\alpha))}-\frac{1-p(\alpha)}{p(\alpha)\cdot f(b(\alpha))}. \qquad (9)$$

and

$$\int_{\underline{c}}^{b(\alpha)}(b(\alpha)-c)f(c)dc-(b(\alpha)-E(c))$$
$$+\alpha\frac{\partial b(\alpha)}{\partial p}\left[p(\alpha)F(b(\alpha))+(1-p(\alpha))\right]-k'(p(\alpha))=0. \qquad (10)$$

When committing to a particular value of α, the owner anticipates the resulting equilibrium $(b(\alpha), p(\alpha))$. Thus, when writing the compensation contract, she is able to set the manager's lump-sum wage w such that the manager just receives the outside utility, S in expectation. Therefore, the owner's expected incremental welfare at stage 0 is given by the entire incremental social surplus or:

$$p(\alpha)\int_{\underline{c}}^{b(\alpha)}(v-c)f(c)dc+(1-p(\alpha))(v-E(c))-k(p(\alpha)). \tag{11}$$

To illustrate the basic tradeoff, I use the following example.

Example: Let c be uniformly distributed over the interval $[0,1]$. Further, let $k(p)$ be given by

$$k(p)=\lambda\cdot\frac{p^2}{1-p}$$

where $\lambda>0$ is a shift parameter for the cost of information acquisition. Ceteris paribus, higher λ generate higher marginal cost of information gathering. In this example, (9) and (10) reduce to:

$$b(\alpha)=\frac{1}{2}\left(v-\frac{1-p(\alpha)}{p(\alpha)}\right) \tag{12}$$

and

$$\frac{1}{2}(b(\alpha)-1)^2+\alpha\cdot\frac{p(\alpha)b(\alpha)+1-p(\alpha)}{p(\alpha)^2} \\ -\frac{2\lambda p(\alpha)}{1-p(\alpha)}-\frac{\lambda p(\alpha)^2}{(1-p(\alpha))^2}=0 \tag{13}$$

Now, for each triple (α,v,λ), (12) and (13) can be solved numerically. Resubstituting into (11) gives the resulting welfare to the owner. Figure 2 shows an examples of how the owner's welfare varies in α for given values of v and λ.

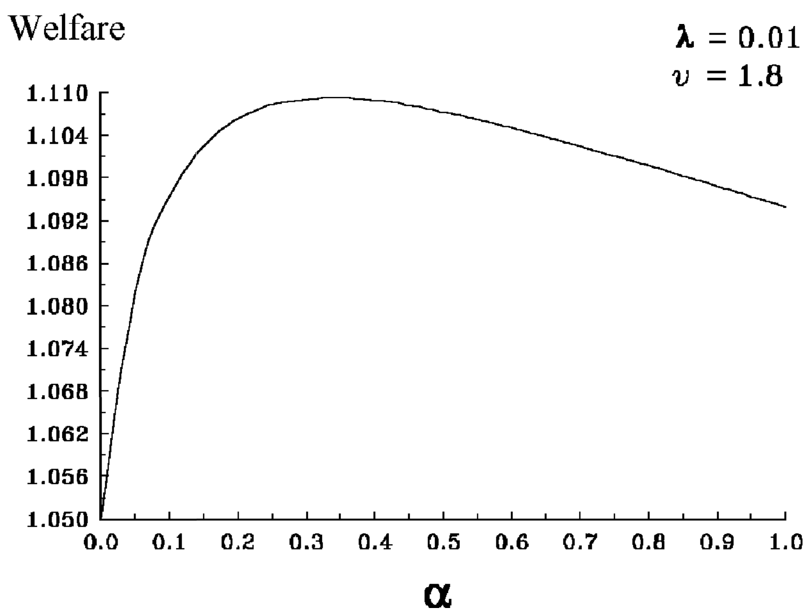

Figure 2: Influence of α on the owner's welfare

In figure 2 the optimal monitoring probability, α^*, is in the interior of the interval $[0, 1]$. However, this property hinges on the specific examle. For other functions $k(p)$, corner solutions occurred quite often. Further computations reveal how the optimal value of α varies with the two exogenous parameters, v and λ. Figure 3, (a) and (b), show that α^* is increasing in v for given λ. Moreover, α^* is decreasing in λ for given v.

The intuition for this final result is that a higher valuation v makes the realization of the project more urgent. Hence, the owner seeks for a device to limit the production distortion. As was shown earlier, monitoring commits the owner to higher budgets than no monitoring. Therefore, α^* is increasing in v (part (a) of the figure). However, the decrease of the production distortion comes at the cost of higher managerial rent seeking activities. Therefore,

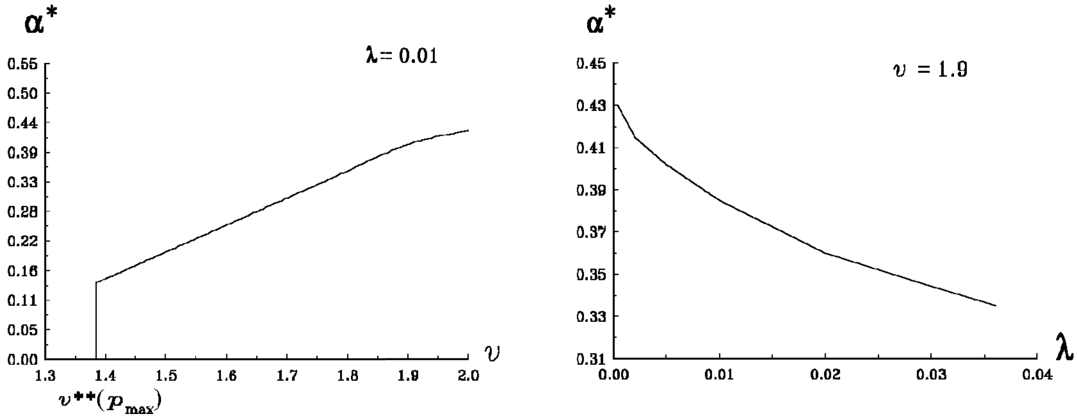

Figure 3: Influence of (a) v and (b) λ on the optimal monitoring probability α^*

also the cost of information acqusition rises. Now, consider figure 3 (b) and an increase in the cost parameter λ for a given valuation v. This increases the marginal cost of information acquisition. Then, a decrease of the monitoring probability economizes on the excess cost induced by the manager's efforts to gather information. Therefore, α^* should be expected to be decreasing in λ. This intuition is confirmed by part (b) of figure 3.

7 *Conclusions*

The paper contains two messages. First, the usual approach to evaluate budgeting mechanisms under adverse selection overestimates the efficiency of the firm. I have shown that there arise stronger output distortions if the manager must spend effort in order to successfully use his information system rather than if he gathers the desired information costlessly. Thus, delegation of decisions is very costly if manager's have to decide about their informational status themselves. This result is in sharp contrast to modern management-folk wisdom which regards delegation as being able to solve most of today's management problems. However, the latter fact just points out the importance of my result.

Moreover, the model contains a very stylized way of investigating the manager's incentives to incur "costs of cost information". Since gathering cost information is costly to the firm, a costing system should and will be imperfect. It should not elicit cost information if this is too expensive, i.e. if the expected value of information is less than its cost. The result of the model is that there may easily arise an efficiency problem with respect to that rationale. I have shown that there arises a managerial incentive to overinvest in the quality of production-cost information. This overinvestment stems from rent-seeking activities started by the manager. Once he is well informed about the cost variables of his responsibility center, he will find opportunities to divert slack into managerial perks.

The decision to monitor the manager's cost of information acquisition should work in a way to economize on the two distortions of production and information gathering activity. Once the owner knows the likelihood that the manager is informed she can adjust the subsequent decision of setting budgets. Hence, in the language of Demski and Feltham (1976) information about the cost k carries both of its roles. It is decision influencing *with re-*

spect to the manager as when spending his information-gathering effort the manager anticipates whether he is evaluated or not. Second, it is decision facilitating *with respect to the owner* as a knowledable owner has the posiibility to adjust the budget. As shown, both roles of cost information are in conflict with each other and give rise to the described tradeoff.

Appendix

Proof of proposition 1. Take the first partial derivative of $E(R_O)$ with respect to b

$$\frac{\partial E(R_O)}{\partial b} = \begin{cases} p[f(b)(v-b) - F(b)] - (1-p) & \text{if } b \geq E(c) \\ p[f(b)(v-b) - F(b)] & \text{if } b < E(c). \end{cases} \tag{14}$$

Consider the lower part of this derivative first. For each $v > \underline{c}$ (14) is positive at $b = \underline{c}$. Therefore, the owner will offer $b > \underline{c}$ for all $v > \underline{c}$. Now, consider $b \in (\underline{c}, v^*]$ where $v^* \equiv E(c) + F(E(c))/f(E(c))$. Consider the budget $b_1(v) = v - F(b_1)/f(b_1)$ as defined in (3). Clearly, at $b_1(v)$ the lower part of (14) vanishes. Moreover, as $F(c)/f(c)$ is increasing in c, the lower part of (14) is decreasing for all $b > \underline{c}$. Hence, the second-order condition is also satisfied and a local maximum has been found. To check the global maximization conditions, observe that for all $v \leq v^*$ both, the upper and the lower part of (14) are negative at $b_1 = E(c)$ and strictly decreasing thereafter. Finally, notice that for $v < v^*$ the upper part of (14) is strictly negative. Hence, $b_1(v)$ is a unique maximizer.

Now, consider $v > v^*$. Then, for all $b \leq E(c)$, the lower part of (14) is strictly positive. Hence, $b(v > v^*) \geq E(c)$, i.e. the upper part of (14) is relevant. Now, for each $v > v^*$ there exists a $p^* > 0$ such that for $p < p^*$ the upper part of (14) is negative and for $p > p^*$ it is positive. Thus, for $p \leq p^*$ the optimal budget is $b_2 = E(c)$. Put differently, for any p there exists a critical $v^{**}(p) \equiv E(c) + \frac{F(E(c))}{f(E(c))} + \frac{1-p}{p \cdot f(E(c))}$ such that for any $v \leq v^{**}$ the upper part of (14) is negative and hence the optimal budget is $b_2 = E(c)$.

Third, consider $v \in (v^{**}(p), \overline{c} + 1/f(\overline{c}))$. Then, the upper part of (14) is positive at $b = E(c)$ and negative at $b = \overline{c}$. Therefore, by continuity of the upper part there exists an interior maximum in $(E(c), \overline{c})$. Then, the optimal budget is necessarily given by

$$\begin{aligned} & p \cdot [(v - b_3) \cdot f(b_3) - F(b_3)] - (1-p) = 0 \\ \Leftrightarrow \quad & b_3 = v - \frac{F(b_3)}{f(b_3)} - \frac{1-p}{p \cdot f(b_3)}. \end{aligned}$$

Notice that because of $v \in (v^{**}(p), \overline{c} + 1/f(\overline{c})]$ we have $b_3 \in (E(c), \overline{c})$ for all $p < 1$. $\square$

Proof of corollary 1. This proof is ommitted. The reader is referred to the original proof by Lewis and Sappington (1993), proposition 1, instead. Their proof is based on a direct revelation mechanism and comes to results consistent to proposition 1.

Proof of lemma 1. Taking the first partial derivative of (6) with respect to p, the agent's best response function is described by the profit-maximization condition

$$0 = \int_{\underline{c}}^{b} (b-c)f(c)dc - k'(p) - \begin{cases} 0 & \text{if } b < E(c) \\ (b - E(c)) & \text{if } b \geq E(c). \end{cases} \tag{15}$$

Investigating the slope of the manager's best response schedule we have

$$\frac{\partial p}{\partial b} = \begin{cases} -\frac{F(b)}{-k''(p)} > 0 & \text{for } b < E(c) \\ -\frac{F(b)-1}{-k''(p)} < 0 & \text{for } b \geq E(c). \end{cases}$$

Hence, for low budgets ($b < E(c)$), the manager's best response is increasing in b whereas it is decreasing for high budgets, ($b > E(c)$). □

Proof of proposition 3. First, denote the necessary efficiency condition associated to (7) as:

$$0 = -k'(p^{eff}) + \int_{\underline{c}}^{b} (v-c)f(c)dc - \begin{cases} [v - E(c)] & \text{if } b \geq E(c) \\ 0 & \text{if } b < E(c). \end{cases} \tag{16}$$

Consider the case of $v < v^*$ first. Then, $b < E(c)$. Now compare the two first-order conditions, namely, the difference of (16) and (15)

$$\int_{\underline{c}}^{b} (v-b)f(c)dc - (k'(p^{eff}) - k'(\hat{p})) = 0$$

$$\Leftrightarrow \quad F(b) \cdot (v-b) = k'(p^{eff}) - k'(\hat{p}) > 0$$

which implies $p^{eff} > \hat{p}$.

Now, consider $v \geq v^*$. Comparison of the relevant first-order conditions now yields

$$[F(b) - 1] \cdot (v-b) = k'(p^{eff}) - k'(\hat{p}) < 0$$

which now implies $p^{eff} < \hat{p}$. $\square$

PROOF OF PROPOSITION 4. Suppose $v > v^{**}(p_{max})$. By proposition 1, the owner's best-response budget is increasing in p. The manager's profit-maximization first-order condition therefore reads to

$$\int_{\underline{c}}^{b(p)} (b(p) - c)f(c)dc - [b(p) - E(c)] \\ + \underbrace{b'(p) \cdot [p \cdot F(b(p)) + (1-p)]}_{\text{strategic effect}} - k'(p) = 0.$$

By (5), $b'(p) > 0$. Therefore, for $v > v^{**}(p_{max})$ $\tilde{p} > \hat{p}$ and $\tilde{b} > \hat{b}$. $\square$

PROOF OF LEMMA 3. To verify part 1, observe that the manager chooses p from an information set consisting of the starting nodes of the two subgames, "monitoring" and "no monitoring." Hence, the probability $p(\alpha)$ does not differ in the two subgames. It follows from the analysis of section 3 that b^+ and b^- do not differ either.

Consider now part 2 of the lemma. Condition (9) is just a replication of (4) derived in proposition 1. Now, consider the derivative of (8) with respect to p.

$$\alpha \left[\int_{\underline{c}}^{b^+} (b^+ - c)f(c)dc - (b^+ - E(c)) \right] \\ +(1-\alpha) \left[\int_{\underline{c}}^{b^-} (b^- - c)f(c)dc - (b^- - E(c)) \right] \\ +\alpha \frac{\partial b^+}{\partial p} [pF(b^+) + (1-p)] = 0$$

which, by part 1, reduces to (10). $\square$

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