Monitoring Selective Reporting: Increasing the Severity or the Probability of Punishment?

Preliminary Version

Abstract

We analyze a model of hard evidence information transmission in which a seller can invest in quality control and disclose the results strategically to a buyer. There is a supervising agency which conducts external quality control and penalizes selective reporting. We focus on the buyer's incentives both for selective reporting and for information search and find that increasing the resources of the agency (the probability of detection) is an inferior monitoring tool than increasing the penalty imposed after selective reporting has been detected. The reason is that–contrary to the standard law enforcement framework–punishment and probability of detection may be complements. We also connect our model to several applications for which monitoring of selective reporting is currently discussed–including the hotly debated topic of disclosure requirements for clinical trials–and derive additional results.

Keywords: persuation games, strategic information transmission, monitoring, penalty, incentives

JEL classification: D82, L15

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1 Introduction

In 2006 a New Jersey jury found that Merck withheld information on Vioxx from the U.S. Food and Drug Administration (F.D.A.) and awarded $4.5 million in compensation to a victim. In order to prevent similar cases the F.D.A. obtained greater authority and more resources to monitor drug safety, including the agency's own meta-analyses of drug safety.[1] In 2010 Toyota Motor paid a $16.4 million civil fine, the largest allowed, because the company failed to promptly notify the National Highway Traffic Safety Administration (N.H.T.S.A.) when Toyota Motor learned of problems with vehicles. As a result of this incident legislators see a need to to update safety standards. Currently discussed legislation intends both to eliminate the cap at $16.4 million and to provide the N.H.T.S.A. with additional financial resources for vehicle safety investigations by the agency. In relation to the Deepwater Horizon oil spill, BP has been accused of detecting safety concerns with the Deepwater Horizon rig far earlier than acknowledged to Congress. Secretary Salazar's reform proposal of oversight of offshore oil and gas operations includes an additional $29 million for inspections, enforcement, studies and other activities. Also, new legislation has been introduced in order to raise a company's maximal liability for economic damages, which is currently capped at $75 million, to $10 billion.

In all these cases the detection of selective reported has triggered reform proposals aiming at monitoring more effectively selective reporting. The reform proposals include provisions that

- raise fines which increase the severity of punishment and/or
- provide additional resources to government agencies in order to detect withholding of information with a higher probability thereby increasing the probability of punishment.

The aim of the present paper is to offer some guidance in the regulatory choice between increasing the severity or the probability of punishment of selective reporting.

A first starting point for guidance in this regulatory choice is the theory of law enforcement. As in the case of a crime, withholding information is socially undesired and regulation should desincentivate it. The literature on optimal law enforcement initiated with the seminal paper of Becker (1968) and relies upon the so-called *deterrence hypothesis* by which agents respond to the desincentives to carry out unlawful activities.[2] The two main tools to provide law enforcement are precisely the severity and probability of punishment. Conventional wisdom following Becker's seminal analysis holds that raising fines is a superior tool than raising detection. The reason is

[1] Improved detection of drug safety issues by a third party is also the aim of a proposal to pool and update continuously all data that emerges from clinical trials in a public database, see Ross et al (2009): "Pooled Analysis of Rofecoxib Placebo-Controlled Clinical Trial Data," Arch Intern Med. 2009;169(21):1976-1985.

[2] See also the survey of Garoupa (1997).

that detection is costly while the fine is a costless monetary transfer. Since the agents respond to the expected punishment, the probability and severity of punishment are perfect substitutes. Raising the fine allows, therefore, to save resources by lowering the detection probability, while keeping the deterrence incentives unaltered.

We build a simple model of selective reporting that differs in one important aspect from Becker's setting. We construct a simple model where an agent wants to sell a product of unknown quality to a potential buyer. Prior to the selling process, the seller can invest in information acquisition about the true quality of the product. The seller can strategically decide not to provide the information to the buyer (selective reporting). In this setting we study the role played by a monitoring agency that can detect and punish selective reporting.

We find that monitoring selective reporting differs from other situations of law enforcement in one very important aspect: monitoring selective reporting creates creates an informational externality that favors the seller. If the agency does not detect that the seller's product is of low quality, this has a positive effect on beliefs of the buyer, who is now more convinced that the product is of high quality. We use the term confidence effect for this informational externality.

Our analysis shows that the confidence effect can be strong enough to induce a complementary relationship between the severity and probability of punishment. This has important strategic effects that affect the capacity of the agency to deter selective reporting. In particular we show that raising the probability of punishment can increase the incentives of the seller to withhold evidence from the buyer. We also look at the incentives of the seller to invest in information search and find that there are situations in which (i) the agency can induce the seller to disclose all the information obtained and (ii) increasing the probability of punishment decreases the incentives for information search, while increasing the severity of punishment does not affect information search. Our results, therefore, provide a new rationale for increasing the severity rather than the probability of punishment of selective reporting.

The paper is organized as follows. The next section discusses the relationship to the different strands of literature to which this paper contributes and puts additional results we obtain for specific applications in context. Section 3 describes our basic model. Section 4 is a benchmark in which there is no supervising agency. Such an agency is introduced in Section 5 which contains our main results. Robustness issues are addressed in Section 6 which we connect to specific applications. We present the conclusions from this study in the last section.

2 Literature

The issues studied in the present paper lie on the crossroad of several strands of literature: clinical trials, law enforcement and disclosure of information about quality by the seller of a good. In what follows we relate our paper to each of them.

2.1 Clinical Trials

There is a small literature analyzing the incentive effects of disclosure regulation in clinical trials. As a result of scandals of selective reporting many parties involved in clinical trials, including the editors of 11 of the most prestigious medical journals, argued in favor of reform of the system (see De Angelis et al., 2004). The main reform proposals are clinical trial registries and clinical trial results databases. The former contains information on ongoing clinical studies, while the latter consists of (a summary of) the results of completed clinical studies, regardless of outcome. Dahm et al. (2009) provide a formal analysis of clinical trial registries and research databases. One of the conclusions of this study is that registries have a deterrence effect on the incentives to conduct clinical trials. Henry E. (2009) provides an alternative theoretical framework and reaches similar conclusions on the deterrence effect of registries.

The present study contributes to this literature because both increasing the severity and raising the probability of punishment are alternative policy tools to registries in monitoring selective reporting. In particular we compare a successful monitoring policy to clinical trial results databases and show that if pharmaceutical firms can commit to use the database before carrying out a clinical trial then results databases are a better regulatory tool because both policies avoid selective reporting but databases provide higher incentives for information search than a successful monitoring policy.

2.2 Law Enforcement

Following Becker's seminal paper a vast literature has developed that studies circumstances where maximum penalties are not optimal (see Garoupa, 1997). Among the different reasons which may advocate for non-maximal penalties are marginal deterrence incentives (Mookherjee and Png, 1992), socially costly sanctions (Kaplow, 1990), differences in wealth among individuals (Polinsky and Shavell, 1991), imperfect information on the probability of aprehension (Bebchuk and Kaplow, 1992) or risk-aversion (Polinsky and Shavell, 1979). The present study contributes to this literature because it provides new support for penalties in the context of selective reporting.

2.3 Disclosure of Information about Quality by a Seller

This literature applies models of information transmission of hard evidence. Classic studies in this literature are Milgrom (1981 and 1986). Milgrom (2008) uses such a framework to analyze persuation and disclosure in markets. Regulation creating liability for withholding information can help to avoid nondisclosure. The present study contributes to this literature because our model can be interpreted as studying a seller who might or might not disclose information affecting the quality of a good to a buyer.

3 The Model

We consider an agent who owns a product he wishes to sell. The revenue obtained from selling the product depends on the perceived 'quality' of the good in the eyes of a potential buyer. The true quality v of the product (v) is, ex-ante, unknown both to the seller and to the buyer. The product can be of high ($v = 1$) or of low quality ($v = 0$). Initially, the probability that the seller's product is of high quality is $q > 0$.

Prior to offering the product for sale, the seller can invest in quality control and conduct research in order to show that his product is of high quality (hereafter we will call this information search a test). Here we have in mind that quality might be affected for example by safety issues or design flaws. The information search can have three possible outcomes. First, the test can demonstrate that the seller's product is of high quality. We will call this outcome a positive test. Second, the test can show that the seller's product is of low quality, a situation to which we will refer as negative test. Third, the test can be inconclusive (i.e., it does not provide any evidence concerning the quality of the good).

Formally, the seller can conduct a test at a cost $K > 0$. The result of the test is denoted by t. The test reveals with probability $x \in [0, 1]$ the true state of the world, that is, $t = v$. With probability $1 - x$, the test is inconclusive, that is, $t = \emptyset$. The information revealed through a test is hard evidence. We denote the seller's report or message by M. If the test reveals that the seller's product is of low quality, that is $t = 0$, then the seller can hide this evidence. Thus, if $t = v$, the seller can decide to publish the result of the test or not, i.e., $M \in \{v, \emptyset\}$. If the test is inconclusive, that is, $t = \emptyset$, then the seller can not forge evidence and has to report this fact, that is, $M = \emptyset$.

There is a supervising agency that prior to the sales process conducts an external quality control. The tests of the agency could, for instance, be triggered by suspicions that the good may have quality problems. We assume that the agency always conducts tests and that these tests detect a flawed product with a probability $\rho \in (0, 1)$.[3] There is no risk of false detection. Formally, denoting by $r \in \{0, \emptyset\}$ the outcome of the agency's report, we have that $\Pr(r = 0|v = 0) = \rho = 1 - \Pr(r = \emptyset|v = 0)$, and $\Pr(r = 0|v = 1) = 0 = 1 - \Pr(r = \emptyset|v = 1)$.

We assume that the seller is required to disclose quality and safety problems. Initially we also

[3] Assuming that the agency conducts tests with probability smaller one, would not change our results. If the agency conducted tests with probability β, it would suffice to make a change of variable and consider $\rho' = \beta\rho$.

suppose that, as part of the screening process, the agency also learns whether the seller already knew that the product was flawed or not. In this case the agency imposes a penalty. More precisely, whenever the agency obtains a report $r = 0$ and detects a withholding of evidence, it will make this information public and impose a fine $F > 0$ on the seller. If $r = 0$ but no evidence was withheld, then the quality problems are disclosed but the firm is not fined. This constitutes the best-case scenario for the supervising agency as it can identify perfectly selective reporting once quality and safety problems have been detected.[4]

The precise timing of this game is as follows:

Stage 1: The seller decides whether to conduct a test.

Stage 2: A message M is sent to the buyer (if no test has been conducted, $M = \emptyset$).

Stage 3: If $M = \emptyset$, the agency conducts its own research and obtains a report r.

Stage 4: Depending on the outcomes of M and r the agency decides whether to impose a fine on the seller, and the buyer updates her beliefs about the perceived 'quality' of the seller's product to $\tilde{q}$.

Stage 5: The sales process takes place.

This game is solved by backward induction. However, instead of solving one specific model for Stage 5, we assume, in principle, any model in which the seller has an incentive to search for information:

Monotonicity Assumption: The equilibrium profits of the seller resulting from the sales process, denoted by $E\Pi(\tilde{q})$, are strictly increasing in its perceived 'quality' $\tilde{q}$.

Finally, as we will see throughout the paper, an important element for the analysis will be the extent to which the market rewards a higher perceived 'quality'. The monotonicity assumption only requires that sellers' profits are increasing in quality, but it does not impose any restriction on the shape of the profit function $E\Pi(\tilde{q})$. It turns out that the following classification is useful. First, we say that the profit function has *increasing returns to quality* whenever the marginal impact of an increase in the perceived 'quality' is increasing in $\tilde{q}$ (i.e., if the profit function is increasing and convex in $\tilde{q}$). Second, we say that the profit function has *decreasing returns to quality* if the marginal effect of an increase in the perceived 'quality' is decreasing (i.e., if the profit function is increasing and concave in $\tilde{q}$).

[4] We choose this set-up in order to show that, even in this favorable scenario, the interaction between F and ρ can give rise to unexpected strategic effects. Section 6 shows the robustness of our results to other modelling choices.

4 The Benchmark Scenario: No Supervising Agency

We study now the benchmark scenario in which there is no agency that monitors the quality of the seller's product. We show that this leads to selective reporting of the evidence that is produced. We also establish as a reference point when it is profitable for the seller to engage in information search.

In this scenario the buyer does not observe the seller's decision whether to invest in a test or not. As a result, she has to base her behavior on her beliefs about what the seller is doing. The appropriate equilibrium concept is, hence, a Perfect Bayesian Equilibrium (PBE) in which all agents behave optimally, given their beliefs about the other's action and these beliefs are, at equilibrium, correct. As usually, there might be multiple equilibria. We focus here on a PBE in which a test is conducted.

Notice first that, given that test results are hard evidence, if the seller reports low quality ($t = 0$), then the buyer will infer $\tilde{q} = 0$. Because of the monotonicity assumption, this message strategy is not a best reply. Consequently, the seller only discloses information that favors his cause. Damaging evidence is hidden. Formally, selective reporting is as follows

$$M = \begin{cases} 1 & \text{if } t = 1 \\ \emptyset & \text{if } t \in \{0, \emptyset\} \end{cases}. \tag{1}$$

If the buyer expects tests to be conducted, beliefs are updated as follows

$$\tilde{q} = \begin{cases} \Pr(v = 1 | M = 1) = 1 & \text{if } M = 1 \\ \Pr(v = 1 | M = 0) = 0 & \text{if } M = 0 \\ \Pr(v = 1 | M = \emptyset) = \frac{\Pr(M=\emptyset|v=1)\Pr(v=1)}{\Pr(M=\emptyset)} = \frac{q(1-x)}{1-xq} \equiv q_x < q & \text{if } M = \emptyset \end{cases}. \tag{2}$$

That is to say, if no evidence is published, taking into account selective reporting, the buyer will infer that it is more likely that the product is of low quality (the true state is 0), since the seller may have received this information and decided not to disclose it (a negative test was conducted).

Given this, the expected profits of the seller from investing in a test are

$$E\Pi_t^B = xqE\Pi(\tilde{q} = 1) + (1 - xq) E\Pi(\tilde{q} = q_x) - K. \tag{3}$$

With probability xq there will be a positive test and the beliefs of the buyer will be $\tilde{q} = 1$. In the remaining cases, however, the test will be negative or inconclusive and the perceived 'quality' diminishes to $\tilde{q} = q_x$. Profits when the seller does not invest in a test are

$$E\Pi_{No\_t}^B = E\Pi(\tilde{q} = q_x). \tag{4}$$

The reason is that the seller is expected to invest and lack of positive test results deteriorates the seller's position vis-a-vis the buyer. The seller invests in the test if and only if

$$E\Pi_t - E\Pi_{No\_t} > 0 \Leftrightarrow K < \mathbb{K}_t^B \equiv xq(E\Pi(\tilde{q} = 1) - E\Pi(\tilde{q} = q_x)).$$

Provided the above inequality holds, this corresponds to a PBE. We summarize this in the following result:

Proposition 1 *In the benchmark scenario without agency, there exists a PBE in which the seller invests in quality control provided this is cheap enough, that is,* $K \leq \mathbb{K}_t^B$. *Moreover, the seller always selectively reports the evidence of those tests.*

So we have seen that in a world without supervising agency, a seller may have incentives to invest in information, but always hides any negative evidence he finds. As usual in these models, there exists also a non-informative equilibrium in which the seller is correctly expected not to run tests.[5]

5 Monitoring by a Supervising Agency

This section studies the effects of external quality control by a supervising agency that might uncover quality problems with the seller's product. We will focus on two main issues: i) Can the risk that the agency detects selective reporting induce the seller to fully reveal all information?; and ii) Does the shadow of the agency foster or deter the seller's incentives to search for information?

5.1 Monitoring and Selective Reporting

To analyze the incentives for selective reporting, we need to compare the seller's profits from selective reporting and disclosing all test results. That is, given $t = 0$, whether $M = \emptyset$ or $M = 0$ is reported. The crucial aspect here are the beliefs of the buyer which depend on whether the agency discovers a flaw with the product (i.e., $r = 0$) or not (i.e., $r = \emptyset$). Beliefs are:

$$\tilde{q} = \begin{cases} \Pr\left(v = 1 | M = 0\right) = 0 & \text{if } M = 0 \\ \Pr\left(v = 1 | M = \emptyset \wedge r = 0\right) = 0 & \text{if } M = \emptyset \wedge r = 0 \\ \Pr\left(v = 1 | M = \emptyset \wedge r = \emptyset\right) = \\ = \frac{\Pr(M=\emptyset|v=1)\Pr(r=\emptyset|v=1)\Pr(v=1)}{\Pr(M=\emptyset \wedge r=\emptyset)} = \frac{q(1-x)}{1-xq-\rho(1-q)} \equiv q_\rho & \text{if } M = \emptyset \wedge r = \emptyset \end{cases} . \quad (5)$$

If the seller "comes clean" and truthfully reports $M = 0$, then he is penalized by the buyer (who will assign probability zero to the event that the product is of high quality) but is not fined by the regulatory agency. In this case, the seller's profits are $E\Pi\left(\tilde{q} = 0\right)$. If, on the other hand, the seller decides to hide the negative evidence, he runs the risk of being detected by the agency. In this case the penalty is double (it is known the the product is of low quality and

[5] Throughout the paper we will focus only on the informative equilibria. An equilibrium without investment in information search exists provided $K > xq\left(E\Pi\left(\tilde{q} = 1\right) - E\Pi\left(\tilde{q} = q\right)\right)$.

the fine F is imposed). If he is not detected, the product remains in the market and the buyer updates the perceived quality to $\tilde{q} = q_\rho \in (0,1)$. Notice for later reference that $q_\rho > q_x$, because the fact that the agency did not find a flaw with the product increases the confidence in the product. We will refer to this effect as the *confidence effect* of agency supervision. Thus, the expected profits from withholding evidence are:

$$\rho \left(E\Pi \left(\tilde{q} = 0 \right) - F \right) + (1 - \rho) E\Pi \left(\tilde{q} = q_\rho \right).$$

This implies the following:

Proposition 2 *For any probability of detection $\rho > 0$, there exists a minimum penalty*

$$\tilde{F}(\rho) \equiv \frac{1-\rho}{\rho} \left(E\Pi \left(\tilde{q} = q_\rho \right) - E\Pi \left(\tilde{q} = 0 \right) \right)$$

such that for any $F \geq \tilde{F}(\rho)$, the seller discloses fully all test results.

This proposition shows that there exist monitoring policies (i.e., pairs (F, ρ)) that can avoid selective reporting. Not surprisingly, these policies are the more successful (i.e. deter the seller in more circumstances), the higher the penalty F.

We analyze now how the two instruments F and ρ interact. As in Becker's law enforcement framework, one would expect that the two monitoring instruments are perfect substitutes: increasing the probability of detection or increasing the fine should both deter selective reporting. In what follows we challenge this intuition and show that whether this is true or not depends on returns from quality.

Proposition 3 *If the seller's profits exhibit* ***decreasing returns to quality*** *then an increase in the probability of detection (ρ) always has a deterrence effect on the incentives for selective reporting.*

Proof. *Consider the minimum value of the penalty preventing selective reporting*

$$\tilde{F}(\rho) \equiv \frac{1-\rho}{\rho} \left(E\Pi \left(\tilde{q} = q_\rho \right) - E\Pi \left(\tilde{q} = 0 \right) \right).$$

An increase in ρ will have a deterrence effect provided $\frac{\partial \tilde{F}(\rho)}{\partial \rho} < 0$, for every $\rho \in (0,1)$. Computing the derivative we obtain:

$$\frac{\partial \tilde{F}(\rho)}{\partial \rho} = \frac{1}{\rho} \left[(1-\rho) \frac{\partial E\Pi}{\partial q}_{|q=q_\rho} \frac{\partial q_\rho}{\partial \rho} - \left(\frac{E\Pi \left(\tilde{q} = q_\rho \right) - E\Pi \left(\tilde{q} = 0 \right)}{\rho} \right) \right].$$

Assume $E\Pi(\tilde{q} = 0)$ (this is without loss of generality as it suffices to rescale the profits when $\tilde{q} \neq 0$).

Using that $\frac{\partial q_\rho}{\partial \rho} = q_\rho \frac{(1-q)}{1-xq-\rho(1-q)}$*, we obtain* $\frac{\partial \tilde{F}(\rho)}{\partial \rho} < 0$ *if and only if*

$$\frac{\frac{\partial E\Pi}{\partial q}|_{q=q_\rho}}{\frac{E\Pi(\tilde{q}=q_\rho)}{q_\rho}} < \frac{1-xq-\rho(1-q)}{(1-\rho)(1-q)\rho}$$

The left hand side (henceforth LHS) of the inequality is smaller than one whenever $E\Pi(\tilde{q})$ *is a concave function. The right hand side (henceforth RHS) of the inequality fulfills*

$$\frac{1-xq-\rho(1-q)}{(1-\rho)(1-q)\rho} > 1 \Longleftrightarrow 1 > xq + (1-q)(2-\rho)\rho,$$

which holds, for every $x, q, \rho \in (0,1)$.

Summing up, we have shown that under decreasing returns to quality (i.e., $E\Pi(\tilde{q})$ *is a concave function), an increase in the probability of detection (*ρ*) always reduces the minimum penalty required to induce complete disclosure.* ■

Consider now the case of increasing returns to quality. We have the following result.

Proposition 4 *If the seller's profits exhibit* ***increasing returns to quality*** *then it is possible to find values of* x *and* q *such that an increase in the probability of detection (*ρ*) increases the seller's incentives for selective reporting.*

Proof. *From the previous proof we know that an increase in* ρ *will not have a deterrence effect on selective reporting provided there exist values of* ρ *such that* $\frac{\partial \tilde{F}(\rho)}{\partial \rho} > 0$*, which occurs if and only if*

$$\frac{\frac{\partial E\Pi}{\partial q}|_{q=q_\rho}}{\frac{E\Pi(\tilde{q}=q_\rho)}{q_\rho}} > \frac{1-xq-\rho(1-q)}{(1-\rho)(1-q)\rho}.$$

Now, it suffices to find values of the parameters that fulfill the above inequality. Consider, for instance, the following profit function $E\Pi(\tilde{q}) = \frac{\tilde{q}^\lambda}{\lambda}$*, with* $\lambda > 1$*. Then the inequality can be rewritten as:*

$$-\rho^2\lambda + (1+\lambda)\rho - \frac{1-xq}{1-q} > 0.$$

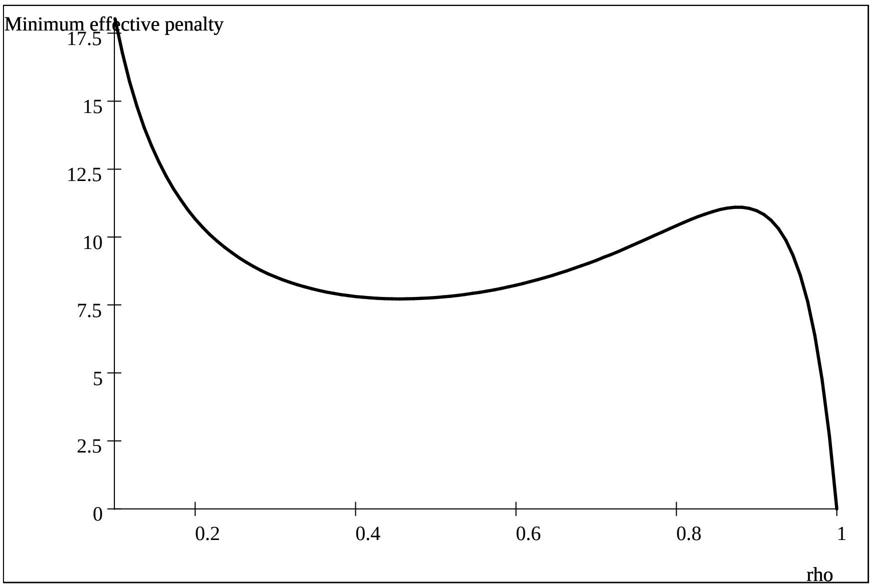
This inequality is fulfilled provided $\rho \in (\rho_L, \rho_H)$*. It remains to show that there exist values for* $\lambda > 1$*,* $x \in (0,1)$ *and* $q \in (0,1)$ *such that* $0 < \rho_L < \rho_H < 1$*. These values can be easily obtained by setting, for instance* $\lambda = 4$*,* $x = 0,6$ *and* $q = 0,4$*. In this case we have* $\rho_L \simeq 0.353$ *and* $\rho_H \simeq 0.897$*.* ■

Surprisingly, stricter supervision by the agency can increase the seller's incentives for selective reporting. The reason is that an increase in the probability of detection ρ has two effects. First, there is a direct *penalty effect:* As ρ increases it is more likely that selective disclosure is detected and the fine is imposed. But second, there is also the indirect *confidence effect:* As ρ increases external quality control becomes better, which increases the buyer's confidence in the product, given that no flaw is detected. When the market rewards high quality generously, the *confidence effect* may dominate and may induce the seller to run the risk of being detected withholding evidence. For illustration consider the following example.

Example 1 *Assume* $E\Pi(\tilde{q}) = \frac{1000}{3}\tilde{q}^3$, $x = 0.2$ *and* $q = 0.2$. *Under these conditions, the minimum penalty needed to avoid selective reporting is:*

$$\tilde{F}(\rho) = \frac{1.365\,333\,333\,(1-\rho)}{\rho\,(0.96-0.8\rho)^3}$$

Plotting this value as a function of ρ*, we have that*



Minimum effective penalty in example 1

It is insightful to draw an analogy to the basic theory of choice under uncertainty. In this analogy the function $E\Pi(\tilde{q})$ takes on the role of the Bernoulli utility function and $\tilde{q}$ the one of income. When the seller's profit function has increasing returns to quality he behaves like a risk-loving agent. This risk-proclivity is the key for the non-monotonicities of the minimum effective penalty in Figure **??**. Notice that the first non-monotonicity coincides with a switch from a substitutive to a complementary relationship of both monitoring instruments. An increase in the monitoring probability increases the risk faced by the seller (it becomes more likely that the withholding of evidence is detected) but, at the same time, it increases the payoffs if no further information is disclosed (as it increases q_ρ). Increasing returns to quality induce the seller to be willing to take more risk and increase his incentives to report evidence selectively, which must be countered by more severe punishment.

We can go one step forward and analyze how changes in the different parameters affect the relevance of the *confidence effect.*

Corollary 1 *The magnitude of the confidence effect is:*

- *Increasing in the degree of convexity of* $E\Pi(\tilde{q})$.
- *Increasing in the probability that the seller's test is informative* (x). Holds if the profit function is of the form $E\Pi(\tilde{q}) = \frac{\tilde{q}^{\lambda}}{\lambda}$.
- *Decreasing in the ex-ante probability that the seller's product is of high quality* (q). Holds if the profit function is of the form $E\Pi(\tilde{q}) = \frac{\tilde{q}^{\lambda}}{\lambda}$.

5.2 Monitoring and Information Search

In this section we investigate the effects of different monitoring policies (ρ, F) on the seller's incentives to invest in information search. As we have seen in the previous section, a monitoring policy (F, ρ) is successful in deterring selective reporting if and only if $F \geq \tilde{F}(\rho)$. We consider both cases successively.

Suppose the policy is unsuccessful and the monitoring policy (F, ρ) cannot avoid selective reporting. In this case the beliefs of the buyer are given by (5) and the seller's expected profits if he searches for information are,

$$E\Pi_t = xqE\Pi(\tilde{q}=1) + ((1-x)q + (1-q)(1-\rho))E\Pi(\tilde{q}=q_\rho) + (1-q)\rho(E\Pi(\tilde{q}=0) - xF) - K. \tag{6}$$

With probability xq there will be a positive test and the beliefs of the buyer will be $\tilde{q} = 1$. However, in the remaining cases the trial will be negative or inconclusive and the perceived 'quality' then shifts to $\tilde{q} = q_\rho$ or $\tilde{q} = 0$ depending on whether the agency detects that the product is flawed or not. If a flaw with the product is detected, in addition the fine is imposed. Profits when the seller does not invest in a test are

$$E\Pi_{No\_t} = (1-(1-q)\rho)E\Pi(\tilde{q}=q_\rho) + (1-q)\rho E\Pi(\tilde{q}=0). \tag{7}$$

The reason is that the seller is expected to invest and lack of positive test results alters the seller's position in the market. Moreover, there is always the risk for the seller that the agency's monitoring detects any flaw in the seller's product. The seller invests in the test if and only if

$$E\Pi_t - E\Pi_{No\_t} > 0 \Leftrightarrow K < \mathbb{K}_t^1 \equiv x\left(q\left(E\Pi(\tilde{q}=1) - E\Pi(\tilde{q}=q_\rho)\right) - (1-q)\rho F\right).$$

We obtain the following result.

Proposition 5 *If the monitoring policy* (F, ρ) *is unsuccessful in avoiding selective reporting, then both an increase in* F *or an increase in* ρ *reduce the seller's incentives to search for information.*

Proof. *It is direct to see that* $\mathbb{K}_t^1$ *is decreasing in* F*. For the effect of an increase in* ρ *it is sufficient to take into account that* $\frac{\partial E\Pi}{\partial q} > 0$ *by the monotonicity assumption and that* $\frac{\partial q_\rho}{\partial \rho} = q_\rho \frac{(1-q)}{1-xq-\rho(1-q)} > 0$*.* ■

While it is not surprising that increasing the fine reduces incentives to search for information (because the seller might be detected withholding evidence), it is surprising that an increase in ρ has a similar effect. Notice that even when there is no fine, that is $F = 0$, the existence of external quality monitoring dissuades information search: $\mathbb{K}_t^1 < \mathbb{K}_t^B$ as $q_x < q_\rho$.

Suppose now that the policy is successful and the monitoring policy (F, ρ) induces complete disclosure. We know that (F, ρ) must be such that $F \geq \tilde{F}(\rho)$ holds and the beliefs of the buyer are given by

$$\tilde{q} = \begin{cases} \Pr(v = 1|M = 0) = \Pr(v = 1|M = \emptyset \wedge r = 0) = 0 & \text{if } M = 0 \text{ or if } M = \emptyset \wedge r = 0 \\ \Pr(v = 1|M = 1) = 1 & \text{if } M = 1 \\ \begin{array}{l} \Pr(v = 1|M = \emptyset \wedge r = \emptyset) = \\ \frac{\Pr(M=\emptyset|v=1)\Pr(r=\emptyset|v=1)\Pr(v=1)}{\Pr(M=\emptyset\wedge r=\emptyset)} = \frac{q}{1-\rho(1-q)} \equiv q_t \end{array} & \text{if } M = \emptyset \wedge r = \emptyset \end{cases} . \tag{8}$$

Notice that, as the seller is not expected to report selectively, we have that $q_t > q_x$. The seller's expected profits from information search are,

$$\begin{aligned} E\Pi_t = {} & xqE\Pi(\tilde{q} = 1) + ((1-x)q + (1-q)(1-x)(1-\rho))E\Pi(\tilde{q} = q_t) \\ & + (1-q)(\rho + x(1-\rho))E\Pi(\tilde{q} = 0) - K. \end{aligned}$$

With probability xq there is a positive test and the beliefs of the buyer are $\tilde{q} = 1$. In the remaining cases, however, the trial is negative or inconclusive and the perceived 'quality' shifts to $\tilde{q} = q_t$ or $\tilde{q} = 0$. The seller's expected profits from not searching for information are,

$$E\Pi_{No\_t} = (1 - (1-q)\rho)E\Pi(\tilde{q} = q_t) + (1-q)\rho E\Pi(\tilde{q} = 0). \tag{9}$$

The seller is expected to invest and the lack of positive test results alters the seller's position in the market. Moreover, there is always the risk that the agency's monitoring detects a flaw with the seller's product. The seller invests in information search if and only if

$$\begin{aligned} & E\Pi_t - E\Pi_{No\_t} > 0 \Leftrightarrow \\ & \quad K < \mathbb{K}_t^2 \equiv xq(E\Pi(\tilde{q} = 1) - E\Pi(\tilde{q} = q_t)) - x(1-q)(1-\rho)(E\Pi(\tilde{q} = q_t) - E\Pi(\tilde{q} = 0)). \end{aligned}$$

From here it follows that,

Proposition 6 *If the monitoring policy* (F, ρ) *is successful and all test results are disclosed, then*

- *If the seller's profits exhibit* ***decreasing returns to quality*** *then for any value of $K \geq 0$, the firm will* ***never*** *find it optimal to invest in information acquisition.*

- *If the seller's profits exhibit* ***increasing returns to quality*** *then it is possible to find values of $K > 0$ such that the firm invests in information acquisition. In this case i) an increase in ρ has a deterrence effect on the incentives to conduct research and ii) and increase in F has no effects on the incentives to conduct research.*

Proof. *First, $\mathbb{K}_t^2$ can be rewritten as*

$$\mathbb{K}_t^2 \equiv x\left(qE\Pi\left(\tilde{q}=1\right) - \left(1-\left(1-q\right)\rho\right)E\Pi\left(\tilde{q}=q_t\right) + \left(1-q\right)\left(1-\rho\right)E\Pi\left(\tilde{q}=0\right)\right)$$

From here it follows that $\mathbb{K}_t^2 \geq 0$ if and only if

$$\frac{q}{1-\left(1-q\right)\rho}E\Pi\left(\tilde{q}=1\right) + \frac{\left(1-q\right)\left(1-\rho\right)}{1-\left(1-q\right)\rho}E\Pi\left(\tilde{q}=0\right) \geq E\Pi\left(\tilde{q}=q_t\right)$$

Since $q_t = \frac{q}{1-(1-q)\rho}$, it follows directly that $\mathbb{K}_t^2 > 0$ if and only if $E\Pi\left(\tilde{q}\right)$ is a convex function (i.e., the firm exhibits increasing returns to quality).

For the second part of the proposition, first, it is direct to see that $\mathbb{K}_t^2$ does not depend on F. For the effect of ρ there are two terms to be taken into account. First, $x\left(1-q\right)\left(1-\rho\right)E\Pi\left(\tilde{q}=0\right)$, which is decreasing in ρ. Secondly, we have the term

$$\phi\left(\rho\right) \equiv x\left(q+\left(1-q\right)\left(1-\rho\right)\right)E\Pi\left(\tilde{q}=q_t\right).$$

Computing $\phi'\left(\rho\right)$ we obtain

$$\phi'\left(\rho\right) = -x\left(1-q\right)E\Pi\left(\tilde{q}=q_t\right) + x\left(q+\left(1-q\right)\left(1-\rho\right)\right)\frac{\partial E\Pi}{\partial q}_{|q=q_t}\frac{\partial q_t}{\partial \rho}.$$

Taking into account that $\frac{\partial q_t}{\partial \rho} = q_t\frac{(1-q)}{q+(1-q)(1-\rho)}$, $\phi'\left(\rho\right)$ can be rewritten as

$$\phi'\left(\rho\right) = -x\left(1-q\right)E\Pi\left(\tilde{q}=q_t\right) + x\left(1-q\right)\frac{\partial E\Pi}{\partial q}_{|q=q_t} q_t > 0 \Longleftrightarrow \frac{E\Pi\left(\tilde{q}=q_t\right)}{q_t} < \frac{\partial E\Pi}{\partial q}_{|q=q_t}.$$

This is equivalent to $E\Pi\left(\tilde{q}\right)$ exhibiting increasing returns to quality. Therefore, in this case, $\mathbb{K}_t^2$ is decreasing in ρ. ■

This proposition shows that, when the firm has decreasing returns to quality the agency faces an unsolvable trade-off. Either its intervention is useless in inducing full transparency or, when it can actually deter selective reporting, then it full deters investment in information.

When there are increasing returns to quality the deterrence effect is not complete. In this case, nevertheless, the *confidence effect* is still present and causes that a seller who is already deterred from withholding evidence is affected by marginal changes in the intensity of the supervision.

6 Applications

The principal objective of this section is to analyze the robustness of our findings so far. We modify our basic model in a variety of ways in order to see when the confidence effect is likely to arise and when it loses force. It turns out that the confidence effect arises in most of these extensions. We connect these modifications of the model to specific instances in which selective reporting is an issue and which might be fruitfully analyzed using our model. In some cases the additional considerations suggested by a specific application allow us to enrich the basic model and to derive further results.

6.1 Recalls

In some situations it is reasonable to assume that the governmental agency imposes a fine whenever it turns out that the underlying state of the world is bad. Consider, for instance, premarket quality control of drugs. Drug makers invest in internal quality control, e.g. by deciding how large the corresponding staff is. In addition the F.D.A. inspects manufacturing plants in order to detect quality control problems. As a result the plant can be shut down and the affected products can be recalled.[6] As this implies a considerable burden for the drug maker, we identify in what follows a recall with F.

In what follows we investigate how the results in Section 5 are affected by this change in the punishment strategy.

First, regarding the incentives to selectively report the information acquired this new set-up makes no difference for the firm. Upon obtaining negative evidence on the quality of the product, the firm can either report this fact (and obtain profits $E\Pi\left(\tilde{q}=0\right)$) or hide this information and face the risk of being spotted by the agency, what yields as expected profits

$$\rho\left(E\Pi\left(\tilde{q}=0\right)-F\right)+\left(1-\rho\right)E\Pi\left(\tilde{q}=q_{\rho}\right).$$

The results in Proposition 2, therefore, continue to hold and provided the policy (ρ, F) is such that $F \geq \tilde{F}(\rho)$ the firm will fully disclose the information it finds.

The analysis, nevertheless, changes when we consider the incentives to invest in information search. Consider first, the case in which the policy is unsuccessful and the monitoring policy (F, ρ) cannot avoid selective reporting. In this case the beliefs of the buyer are given by (5) and the seller's expected profits if he searches for information are,

$$E\Pi_t = xqE\Pi\left(\tilde{q}=1\right)+\left(\left(1-x\right)q+\left(1-q\right)\left(1-\rho\right)\right)E\Pi\left(\tilde{q}=q_{\rho}\right)+\left(1-q\right)\rho\left(E\Pi\left(\tilde{q}=0\right)-F\right)-K. \tag{10}$$

[6] The New York Times (May 26th, 2010) reports that after an F.D.A. inspection the drug maker McNeil shut down the plant and recalled the liquid children's products.

This expression differs from equation (6) in that, now, the fine is paid when there are quality problems with the product even when selective reporting did not occur. Profits when the seller does not invest in information search are

$$E\Pi_{No\_t} = (1-(1-q)\,\rho)\,E\Pi\,(\tilde{q}=q_\rho) + (1-q)\,\rho\,(E\Pi\,(\tilde{q}=0) - F)\,. \tag{11}$$

Again, compared with equation (7) the difference lies in the fact that the firm may be fined, even if no evidence was withheld. From here, it follows that the seller invests in the test if and only if

$$E\Pi_t - E\Pi_{No\_t} > 0 \Leftrightarrow K < \mathbb{K}_{SR}^{recall} \equiv xq\,(E\Pi\,(\tilde{q}=1) - E\Pi\,(\tilde{q}=q_\rho))\,.$$

Suppose now that the policy is successful and the monitoring policy (F,ρ) induces that all test results are disclosed. In this case, the beliefs of the buyer are given by (8). The seller's expected profits from information search are,

$$\begin{aligned} E\Pi_t = xqE\Pi\,(\tilde{q}=1) + ((1-x)\,q + (1-q)\,(1-x)\,(1-\rho))\,E\Pi\,(\tilde{q}=q_t) \\ + (1-q)\,(xE\Pi\,(\tilde{q}=0) + (1-x)\,\rho\,(E\Pi\,(\tilde{q}=0) - F)) - K. \end{aligned}$$

The seller's expected profits from not searching for information are,

$$E\Pi_{No\_t} = (1-(1-q)\,\rho)\,E\Pi\,(\tilde{q}=q_t) + (1-q)\,\rho\,(E\Pi\,(\tilde{q}=0) - F)\,. \tag{12}$$

The seller invests in information search if and only if

$$\begin{aligned} &E\Pi_t - E\Pi_{No\_t} > 0 \Leftrightarrow K < \mathbb{K}_{Tr}^{recall}, \text{ with} \\ &\mathbb{K}_{Tr}^{recall} \equiv x\,(q\,(E\Pi\,(\tilde{q}=1) - E\Pi\,(\tilde{q}=q_t)) - (1-q)\,(1-\rho)\,(E\Pi\,(\tilde{q}=q_t) - E\Pi\,(\tilde{q}=0)) + \rho\,(1-q)\,F)\,. \end{aligned}$$

It is direct to see that $\mathbb{K}_{SR}^{recall}$ is independent of F, while $\mathbb{K}_{Tr}^{recall}$ is increasing in F. We see that when a policy penalizes directly quality problems rather than selective reporting, then the deterrence effect of punishment on information search disappears. We summarize with the following corollary:

Corollary 2 *In a setting with product recalls, the effects of a monitoring policy (F,ρ) on the incentives to invest in information acquisition are as follows.*

- *An increase in the fine F:*
  - *Has no effects on the incentives to invest in information when the policy is unsuccessful.*
  - ***Always increases** the incentives to invest in information when the policy is successful.*

- *An increase in the probability of detection ρ:*
  - ***Always decreases*** *the incentives to invest in information when the policy is unsuccessful.*
  - *Has an ambiguous effect on the incentives to invest in information when the policy is successful.*

This allows us to conclude that the results of Section 5 are not only robust to a change in the set-up such that quality problems are punished rather than selective reporting, but the dominance of F over ρ is even greater than in the original model in the following sense:

i) Concerning the incentives for selective reporting the conclusions are the same.

ii) Concerning the incentives to invest in information search: An increase in F increases these incentives always, at least weakly, while an increase in ρ is likely to have a deterrence effect.

6.2 Corporate Audits

In some situations it is reasonable to assume that the governmental agency tries to detect selective reporting rather than the underlying state of the world. For instance, during BP's drilling for oil in the Gulf of Mexico the Minerals Management Service (M.M.S.) reviewed documentation provided by BP and gave permission for the company's strategy to prevent accidents.[7] Another example are corporate audits. In many countries the management of public companies is required to prepare financial statements (e.g. the balance sheet and cash flow). These statements must be audited by independent auditors. In order to fix ideas we use in what follows the illustration of corporate audits.[8]

Auditing can only reveal problems when information has been withheld. In this case auditing reveals withholding of information with probability $\alpha = \Pr(a = 0 | t = 0 \text{ and } M = \emptyset) \in (0,1)$, where $a \in \{0, \emptyset\}$. If no information has been withheld auditing cannot reveal the state of the world $\Pr(a = 0 | t \neq 0 \text{ or } M \neq \emptyset) = 0 = 1 - \Pr(a = \emptyset | t \neq 0 \text{ or } M \neq \emptyset)$.

[7] Note that in the context of this example there are concerns that BP withheld information. The New York Times (May 29th, 2010) reports that in a permit request "company officials apologized to federal regulators for not having mentioned the type of casing they were using earlier, adding that they had "inadvertently" failed to include it. In the permit request, they did not disclose BP's own internal concerns about the design of the casing."

[8] Notice that our model can be viewed as a simplified version of Shin's (2003) model in which the value of a firm only depends on one project but the payoff function of the firm is more general. In addition the company's financial disclosures are audited. The agency can also be interpreted as other watchdogs like investors or the financial press.

The investor's beliefs are:

$$\tilde{q} = \begin{cases} \Pr(v=1|M=0)=0 & \text{if } M=0 \\ \Pr(v=1|M=\emptyset \wedge a=0)=0 & \text{if } M=\emptyset \wedge a=0 \\ \Pr(v=1|M=\emptyset \wedge a=\emptyset)= & \\ = \frac{\Pr(M=\emptyset|v=1)\Pr(a=\emptyset|v=1)\Pr(v=1)}{\Pr(M=\emptyset \wedge a=\emptyset)} = \frac{q(1-x)}{1-xq-\alpha x(1-q)} \equiv q_\alpha & \text{if } M=\emptyset \wedge a=\emptyset \end{cases}. \tag{13}$$

Notice that the confidence effect still exists, since $q_x < q_\alpha$. But it is smaller than in the benchmark case, as $q_\alpha < q_\rho$. The reason is that the monitoring technology is now less powerful. It does not provide useful information to the investor when $t = \emptyset$.

It is straightforward to derive the following result.

Proposition 7 *For any probability of detection $\alpha > 0$, there exists a minimum penalty*

$$\tilde{F}(\alpha) \equiv \frac{1-\alpha}{\alpha}\left(E\Pi(\tilde{q}=q_\alpha) - E\Pi(\tilde{q}=0)\right)$$

such that for any $F \geq \tilde{F}(\alpha)$, the seller discloses fully all test results.

Notice that in general there is no unambiguous relationship between $\tilde{F}(\rho)$ and $\tilde{F}(\alpha)$. If, however, $\alpha \geq \rho$, then $\tilde{F}(\rho) > \tilde{F}(\alpha)$. As the confidence effect is weaker, it becomes "easier" to monitor selective reporting.

Although the confidence effect is weaker and, thus, an increase in the probability of detection increases the seller's incentives for selective reporting in fewer situations,[9] the conclusions concerning the incentives for selective reporting are robust.

Proposition 8 *The incentives for selective reporting are as follows:*

- *If the seller's profits exhibit* ***decreasing returns to quality*** *then an increase in the probability of detection (α) always has a deterrence effect on the incentives for selective reporting.*

- *If the seller's profits exhibit* ***increasing returns to quality*** *then it is possible to find values of x and q such that an increase in the probability of detection (α) increases the seller's incentives for selective reporting.*

Proof. *The proof follows the same lines as in the benchmark.* ■

[9] This can be made precise. In the benchmark

$$\frac{\frac{\partial E\Pi}{\partial q}_{|q=q_\rho}}{\frac{E\Pi(\tilde{q}=q_\rho)}{q_\rho}} > \frac{1-xq-\rho(1-q)}{(1-\rho)(1-q)\rho}$$

must be fulfilled. With auditing the RHS is multiplied by $1/x$.

The conclusions concerning the incentives for information search are also robust.

Proposition 9 *If the monitoring policy (F, α) is unsuccessful in avoiding selective reporting, then*

- *the firm invests in information search if and only if $K < \mathbb{K}_t^a$, where*

$$\mathbb{K}_t^a \equiv xq\left(E\Pi\left(\tilde{q}=1\right) - E\Pi\left(\tilde{q}=q_\alpha\right)\right) - x\alpha\left(1-q\right)\left(E\Pi\left(\tilde{q}=q_\alpha\right) - E\Pi\left(\tilde{q}=0\right) + F\right);$$

- *both an increase in F or an increase in α reduce the seller's incentives to search for information.*

Proof. *The proof follows the same lines as in the benchmark.* ■

Given that $\mathbb{K}_t^a < \mathbb{K}_t^1$, the incentives to invests in information search are reduced compared to the benchmark. This is mainly due to the fact that the agency only checks the statements of the firm and does not search for the true state of the world, which increases the firm's opportunity costs of doing research.

6.3 Selective Reporting of Clinical Trial Results

As we have explained in the introduction selective reporting of clinical trials results is an important problem. In the U.S. new drugs are approved by the Food and Drug Administration (FDA). Once a drug is in the market every patient adverse drug experience must be reviewed and reported to the FDA.[10] The FDA has an Adverse Event Reporting System (AERS) database which contains information about adverse drug event reports obtained through voluntary reporting by consumers and health professionals.[11] The Food and Drug Administration Amendments Act (FDAAA), which was signed into law on September 27, 2007, is considered to be a landmark legislation. It gave the FDA new resources of $225 million over five years, modernized AERS and complemented it through other databases, endowed the FDA with the power to require postmarketing studies, as well as gave it the authority to impose financial penalties and other legal sanctions (see Schultz, 2007).

Dahm et al (2009) have argued that for pharmaceutical firms the assumption of increasing returns to quality is reasonable. Under this assumption, the analysis so far imply that increasing the probability of detection (resources)

- can worsen the problem selective reporting. Increasing financial penalties is a more effective measure.

[10] 21 CFR 314.80: Postmarketing Reporting of Adverse Drug Experiences.

[11] http://www.fda.gov/Safety/MedWatch/default.htm

- deters firms from investing in clinical trials, even if the firm fully discloses results.

In this section we suppose there exists a commitment device that, once a clinical trial has been carried out, makes selective reporting impossible. In the context of clinical trials this assumption can be motivated in two ways. First, as external clinical trials. For instance, the National Cancer Institute has been given funding in order to conduct clinical trials. Second, as results databases. To fix ideas in what follows we associate the commitment device with results databases.

Pharmaceutical firms can, voluntarily, commit to post their results in a database and, by doing so, they forego their capacity to strategically withhold evidence. In the terminology of Dahm and Porteiro (2008) the results databases turn the clinical trials into a "public test".

The firm can also choose not to use the database. In this case the market participants will expect the firm to selectively report the findings of the clinical trial and, as a result, their beliefs will be given by (5). With this, the expected profits of the firm if it conducts a clinical trial and selectively reports its findings are

$$E\Pi_t^{SR} = xqE\Pi\left(\tilde{q}=1\right)+\left(\left(1-x\right)q+\left(1-q\right)\left(1-\rho\right)\right)E\Pi\left(\tilde{q}=q_\rho\right)+\left(1-q\right)\rho\left(E\Pi\left(\tilde{q}=0\right)-xF\right)-K. \tag{14}$$

If the firm decides to use the commitment device, then it becomes transparent and, therefore, the market beliefs are given by (8). With this, therefore, the expected profits of the firm if conducts a trial are,

$$\begin{aligned} E\Pi_t^{Tr} = xqE\Pi\left(\tilde{q}=1\right)+\left(\left(1-x\right)q+\left(1-q\right)\left(1-x\right)\left(1-\rho\right)\right)E\Pi\left(\tilde{q}=q_t\right) \\ +\left(1-q\right)\left(\rho+x\left(1-\rho\right)\right)E\Pi\left(\tilde{q}=0\right)-K. \end{aligned}$$

This implies that there exists an alternative mechanism that can eliminate the problem of selective reporting without having to resort to a supervision/penalty system.

Proposition 10 *For any (F,ρ) if the pharmaceutical firm has* ***increasing returns to quality,*** *then it finds it optimal to commit to post its results in a database.*

Proof. *By comparing $E\Pi_t^{SR}$ with $E\Pi_t^{Tr}$ we find that the firm prefers to disclose results to a database if and only if*

$$\begin{aligned} xF \geq \frac{(1-\rho)}{\rho}\left(E\Pi\left(\tilde{q}=q_\rho\right)-xE\Pi\left(\tilde{q}=0\right)\right) \\ +\frac{(1-x)}{(1-q)\rho}\left(qE\Pi\left(\tilde{q}=q_\rho\right)-\left(1-\left(1-q\right)\rho\right)E\Pi\left(\tilde{q}=q_t\right)\right) \end{aligned}$$

Since $E\Pi\left(\tilde{q}=0\right)\geq 0$, a sufficient condition for the firm to be always willing to commit to using the database is:

$$\frac{(1-\rho)}{\rho}E\Pi\left(\tilde{q}=q_\rho\right)+\frac{(1-x)}{(1-q)\rho}\left(qE\Pi\left(\tilde{q}=q_\rho\right)-\left(1-\left(1-q\right)\rho\right)E\Pi\left(\tilde{q}=q_t\right)\right)\leq 0$$

Rearranging terms, this inequality is equivalent to

$$(1-\rho(1-q)-xq)\,E\Pi(\tilde{q}=q_\rho)-(1-x)(1-(1-q)\rho)\,E\Pi(\tilde{q}=q_t)\leq 0$$

or,

$$\frac{E\Pi(\tilde{q}=q_\rho)}{\frac{q(1-x)}{1-\rho(1-q)-xq}}\leq\frac{E\Pi(\tilde{q}=q_t)}{\frac{q}{1-\rho(1-q)}}\Longleftrightarrow\frac{E\Pi(\tilde{q}=q_\rho)}{q_\rho}\leq\frac{E\Pi(\tilde{q}=q_t)}{q_t}$$

Since $q_t > q_\rho$, the above inequality is verified for any parameter constellation provided $E\Pi(\tilde{q})$ is a convex function (i.e., it exhibits increasing returns to quality). ■

We compare now the incentives to invest in information search of a commitment device to make use of a results database with a successful monitoring policy (i.e., with $F \geq \tilde{F}(\rho)$).

Corollary 3 *Comparing a successful monitoring policy (F,ρ) and a commitment device to use databases, we have that:*

- *Both policies induce honest reporting.*
- *The commitment device always provides more incentives for information search.*

  Proof. *The first bullet is straightforward from the definition of a successful policy and Proposition 10. To prove the second bullet we use the fact that, with a successful monitoring policy, the firm invests in information search provided $K \leq \mathbb{K}_t^2$,with*

  $$\mathbb{K}_t^2\equiv x\left(qE\Pi(\tilde{q}=1)-(1-(1-q)\rho)\,E\Pi(\tilde{q}=q_t)+(1-q)(1-\rho)\,E\Pi(\tilde{q}=0)\right)$$

  If the firm decides to use the commitment policy then, if it invests in information search its profits are

  $$E\Pi_t^{Tr}=xqE\Pi(\tilde{q}=1)+(1-x)\,E\Pi(\tilde{q}=q_t)+x(1-q)\,E\Pi(\tilde{q}=0)-K.$$

  while if it does not invest, its profits are given by $E\Pi_{Not}^{Tr}=E\Pi(\tilde{q}=q_t)$.Comparing we have that the firm invests in information search if

  $$K\leq\mathbb{K}_t^{Tr}\equiv x\left(qE\Pi(\tilde{q}=1)+(1-q)\,E\Pi(\tilde{q}=0)-E\Pi(\tilde{q}=q_t)\right).$$

  It is straightforward to check that for every $\rho>0$, it holds that $\mathbb{K}_t^{Tr}>\mathbb{K}_t^2$. Moreover, $\lim_{\rho\to 0}\mathbb{K}_t^2=\mathbb{K}_t^{Tr}$. ■

This corollary provides a strong argument in favor of commitment policies and against monitoring policies because the commitment devices provides higher incentives for information search.

6.4 Quality Monitoring in Manufacturing Firms

The model can be useful to study the incentives of manufacturing firms to run quality tests and to make this information fully available to the public. To analyze this problem we slightly modify our setting by giving a more realistic but less powerful technology to the monitoring agency. We will assume that selective reporting is not directly observed by the agency as part of the information it obtains if its report shows that the product is flawed (i.e., that $q = 0$). Instead, we consider a rational expectations equilibrium in which the agency imposes the penalty F if it (correctly) anticipates that the firm had incentives to invest in information and to selectively report any negative evidence it may find.

The question is whether under this assumption the desincentive effects of an increase in ρ on selective reporting and investment in information search still exist. To answer it we need to construct the rational expectations equilibria. First, does a Perfect Bayesian equilibrium exist in which the agency expects the firm to search for information and report selectively the results? The answer is yes, provided the fine imposed after selective reporting has been discovered does not exceed the critical value $\tilde{F}(\rho)$ defined in Proposition 2. Formally,

Proposition 11 *If the monitoring policy (F, ρ) is unsuccessful in avoiding selective reporting and the cost of information search is $K \leq \mathbb{K}_t^3$, then there exists a PBE in which the firm searches for information and reports results selectively, where*

$$\mathbb{K}_t^3 = xq\left(E\Pi\left(\tilde{q} = 1\right) - E\Pi\left(\tilde{q} = q_\rho\right)\right).$$

Proof. *First, we consider the decision to carry out the test. If the agency expects the firm to run the test and selectively report its findings, the beliefs of the agency about q will be given by (5). Moreover, whenever the agency obtains a report $r = 0$, it will impose a penalty F on the firm. With this, therefore, the expected profits of the firm if it runs a test are,*

$$E\Pi_t = xqE\Pi\left(\tilde{q} = 1\right) + \left(\left(1 - x\right)q + \left(1 - q\right)\left(1 - \rho\right)\right)E\Pi\left(\tilde{q} = q_\rho\right) + \left(1 - q\right)\rho\left(E\Pi\left(\tilde{q} = 0\right) - F\right) - K.$$

Profits when the firm does not invest in a test are

$$E\Pi_{No\_t} = \left(1 - \left(1 - q\right)\rho\right)E\Pi\left(\tilde{q} = q_\rho\right) + \left(1 - q\right)\rho\left(E\Pi\left(\tilde{q} = 0\right) - F\right).$$

From here, it follows directly that the firm will invest in research provided

$$K \leq \mathbb{K}_t^3 \equiv xq\left(E\Pi\left(\tilde{q} = 1\right) - E\Pi\left(\tilde{q} = q_\rho\right)\right).$$

To sustain this as a PBE we have also to verify the disclosure behaviour of the firm. If the firm upon observing $t = 0$ truthfully reports $M = 0$, its profits are $E\Pi\left(\tilde{q} = 0\right)$. If the firm decides to hide the negative evidence, the expected profits are:

$$\rho\left(E\Pi\left(\tilde{q} = 0\right) - F\right) + \left(1 - \rho\right)E\Pi\left(\tilde{q} = q_\rho\right).$$

From here it follows directly that the firm will find it optimal to withhold evidence if $F \leq \tilde{F}(\rho)$, *with* $\tilde{F}(\rho) = \frac{1-\rho}{\rho}(E\Pi(\tilde{q} = q_\rho) - E\Pi(\tilde{q} = 0))$ *as in Proposition 2.* ■

Several comments are in order:

Corollary 4 *The effects of changes in the monitoring policy* (ρ, F) *are:*

i) *When the firm exhibits increasing returns to quality, an increase in probability of detection* ρ *can increase the minimum value of the penalty required to eliminate the equilibrium where the firm selectively reports evidence.*

ii) *When the firm selectively reports evidence, an increase in the penalty* F *does not have any deterrence effect on the incentives to conduct research.*

iii) *When the firm selectively reports evidence, an increase in the probability of detection* ρ *has a deterrence effect on the incentives to conduct research.*

Proof. To prove i) it suffices to use that the threshold derived is the same as in Proposition 2. The results in Proposition 4 directly apply. Item ii) is direct since $\mathbb{K}_t^3$ does not depend on F. Finally, iii) can be shown using the fact that $\mathbb{K}_t^3$ is decreasing in q_ρ and q_ρ is increasing in ρ. ■

So, when the the monitoring policy is unsuccessful in avoiding selective reporting, the results are very consistent with the ones in the main body of the paper. The only difference is that, since the penalty is based on beliefs (instead of on the certainty that the firm behaved incorrectly), there may be instances in which, although the firm does not search for information, it will be penalized. This increases the incentives to search for information as it eliminates the deterrence effect of the penalty.

Now, if $F > \tilde{F}(\rho)$ and an equilibrium with selective reporting does not exist, does there exist an equilibrium with complete disclosure? The answer is no.

Proposition 12 *There does not exist a PBE in which the agency correctly expects the firm to search for information and the firm discloses results completely.*

Proof. *The proof is very simple. If the agency expects the firm to conduct research and always report its findings then, upon observing no evidence from the firm, it will not impose any penalty. With this, if the firm decides to hide a negative test result, its expected profits are* $\rho E\Pi(\tilde{q} = 0) + (1-\rho) E\Pi(\tilde{q} = q_\rho)$ *that are always higher than the profits it obtains if it reports the evidence found* ($E\Pi(\tilde{q} = 0)$)*. Therefore, reporting negative evidence is not an optimal behaviour and no PBE can be built upon such beliefs.* ■

So, if for $F > \tilde{F}(\rho)$ there does not exist either an equilibrium with selective reporting or one with transparency, what is the outcome of the interaction? A probabilistic behaviour (mixed-strategies equilibrium) where the firm *sometimes* withholds evidence. Consider the following behaviour for the agency: It assigns a probability $\alpha \in (0,1)$ to the event that the firm, upon receiving negative evidence (i.e., $t = 0$), decides to hide it. Consequently, if the agency obtains a report $r = 0$, it will impose a penalty F on the firm, with probability α.

These beliefs affect the posterior probability that the potential buyer assigns to $v = 1$, if both $M = \emptyset$ and $r = \emptyset$ to:

$$q_\alpha \equiv \frac{q(1-x)}{1 - xq - (1-q)(\rho + (1-\rho)x(1-\alpha))}.$$

This behaviour can be part of a PBE as the following proposition shows.

Proposition 13 *If the monitoring policy (F, ρ) is successful in avoiding selective reporting and the cost of information search is $K \leq \mathbb{K}_t^4$ then there exists a "partially transparent" PBE in which the firm searches for information and reports selectively negative tests with probability $\alpha^* \in (0,1)$, where*

$$\mathbb{K}_t^4 = xq\left(E\Pi\left(\tilde{q} = 1\right) - E\Pi\left(\tilde{q} = q_\alpha\right)\right)$$

and α^* is the solution to

$$F = \frac{1-\rho}{\rho}\left(\frac{E\Pi\left(\tilde{q} = q_\alpha\right) - E\Pi\left(\tilde{q} = 0\right)}{\alpha}\right)$$

Proof. *Consider first the decision to search for information. If the agency expects the firm to search and selectively report results with probability α, the beliefs of the agency about q will be given by (5), with q_α instead of q_ρ. Moreover, if the agency obtains a report $r = 0$, it will impose a penalty F on the firm with probability α. With this the firm's expected profits from investing in a test are,*

$$E\Pi_t = xqE\Pi\left(\tilde{q} = 1\right) + \left((1-x)q + (1-q)(1-\rho)\right)E\Pi\left(\tilde{q} = q_\alpha\right) + (1-q)\rho\left(E\Pi\left(\tilde{q} = 0\right) - \alpha F\right) - K.$$

If the firm does not invest in a test profits are

$$E\Pi_{No\_t} = \left(1 - (1-q)\rho\right)E\Pi\left(\tilde{q} = q_\rho\right) + (1-q)\rho\left(E\Pi\left(\tilde{q} = 0\right) - \alpha F\right).$$

It follows directly that the firm will invest in research provided

$$K \leq \mathbb{K}_t^4 \equiv xq\left(E\Pi\left(\tilde{q} = 1\right) - E\Pi\left(\tilde{q} = q_\alpha\right)\right).$$

To sustain this as a PBE we also have to verify that after observing $t = 0$, the firm is indifferent between truthfully reporting $M = 0$ and selective reporting. In the former case it obtains $E\Pi\left(\tilde{q} = 0\right)$, while in the latter case expected profits are

$$\rho\left(E\Pi\left(\tilde{q} = 0\right) - \alpha F\right) + (1-\rho)E\Pi\left(\tilde{q} = q_\alpha\right).$$

It follows that the value of α that sustains this equilibrium as a mixed-strategies PBE is the solution to

$$F = \frac{1-\rho}{\rho}\left(\frac{E\Pi\left(\tilde{q} = q_{\alpha}\right) - E\Pi\left(\tilde{q} = 0\right)}{\alpha}\right)$$

Moreover, it is easy to see that the above condition has a solution $\alpha^* \in (0,1)$ provided $F > \tilde{F}(\rho)$ and that α^* is decreasing in F. ■

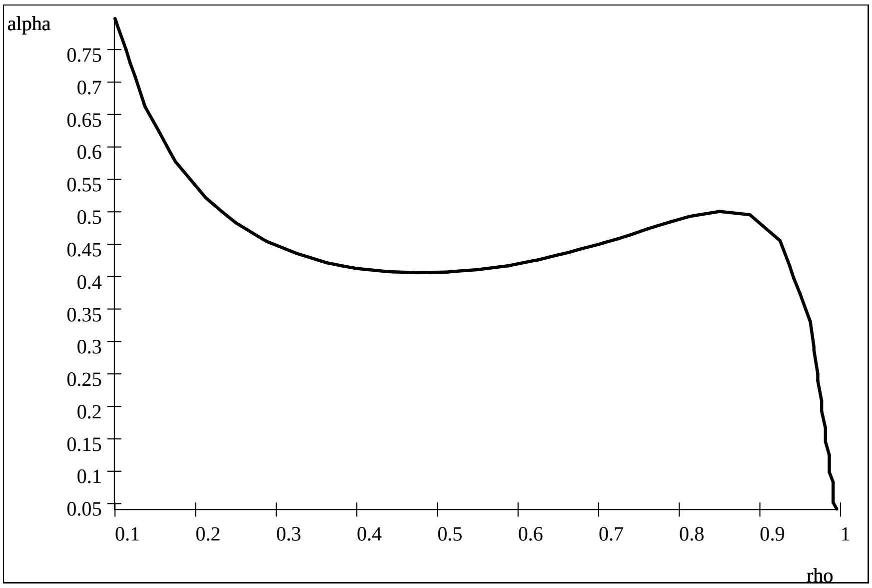
The main message of this proposition is that, when the agency cannot directly observe whether there has been selective reporting or not and has to base its decision to punish the firm on beliefs, then it is impossible to fully deter selective reporting. The higher the penalty, the higher the probability that the firm discloses results completely, but this probability is always smaller than one.[12]

We analyze now whether the *confidence effect* can create non-monotonicities even in this partially transparent equilibrium. For a given penalty level F, can an increase in ρ increase the equilibrium probability that the firm reports results selectively? The answer is yes.

Example 2 *Consider the following particular case: $E\Pi(q) = \frac{1000}{3}q^3$, $x = 0.2$, $q = 0.2$ and a penalty $F = 25$ With these data, the equilibrium probability that the firm decides to withhold evidence (α^*) is the solution to:*

$$25 = \frac{1.365\,333\,333\,(1-\rho)}{\alpha^*\rho\left(0.96 - 0.16\left(1-\alpha^*\right)(1-\rho) - 0.8\rho\right)^3}$$

If we plot this value as a function of ρ we have that



[12]Notice that it is direct to show that $K_t^4 > K_t^2$, so there are more incentives to conduct tests for firms that "sometimes" withhold evidence than for those that always report truthfully.

7 Concluding Remarks

We have analyzed a model of selective reporting in which there is monitoring by an agency. This model can be applied to several important situations including selective reporting of clinical trials. Our results provide new support for the conclusion of the law enforcement literature that increasing the severity of punishment is a better regulatory tool than increasing its probability.

For the context of clinical trials we have also analyzed the incentive effects of a currently discussed policy, the clinical trial result databases, and provided new support for them. More precisely, we have shown that an interested party might prefer information search by a third party to carry out its own search. This result speaks also to other situations. An example is in-house inquiries versus independent investigations after an accident. While in the U.S. federal agencies often investigate accidents in areas they regulate, several independent commissions have been created in order to avoid that an agency investigates itself. A recent example is the National Academy of Engineering which–instead of the Minerals Management Service–will conduct an independent investigation to determine the causes of the Deepwater Horizon disaster. Other examples are the National Transportation Safety Board (which has final investigative authority over the Department of Transportation), the Kemeny Commission (which studied the Nuclear Regulatory Commission) or the the special board that investigated the crash of the space shuttle Columbia (and investigated NASA). These independent commissions were created in order to avoid, for example, that evidence might be withheld. In this context our result is interesting because it suggests that in some circumstances even the agency which is subject to the inquiry might prefer an independent investigation.

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