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THE PRINCIPLE OF MAXIMUM DETERRENCE REVISITED

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Abstract

This paper shows that it may be desirable to deter crime by imposing the largest feasible penalties on offenders even though it is possible that an innocent person may be convicted. Thus the fear of punishing an innocent does not by itself explain why penalties are limited in size. It is shown, however, that the combination of conviction errors and the impossibility of committing oneself to an investigation policy produces optimal penalties of limited size.

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I. Introduction

In his seminal paper "Crime and Punishment" Becker (1962) asked about the optimal system of law enforcement when apprehension of offenders is costly. What punishments should society specify and what resources should it spend in order to deter crime optimally? One of the main ideas emerging from his analysis is the Principle of Maximum Deterrence: In order to save on the cost of discovering and convicting offenders, the optimal procedure is often to set the strongest possible penalties available. In contemplating committing a crime, a risk-neutral individual compares the expected cost of committing the offense (given by P, the probability of being apprehended, times F, the penalty imposed if discovered) with the benefit. By increasing F, society can reduce P (keeping the expected cost constant) and thereby save what it would otherwise spend on deterrence and detection.

When individuals are risk-neutral, the principle of maximum deterrence holds in two separate cases: First, cases in which it is optimal to deter everybody from committing an offense, and, second, cases in which society may not want systematically to deter all individuals from committing certain offenses (for example, it may be welfare-improving to allow some people occasionally to double-park).

However, Polinsky and Shavell (1979) have shown that when agents are risk-averse, then in the second case it is not optimal to have infinitely large penalties.[(1)] They explain that the lower the probability of detection and the higher the fine, the more risky it is for those who have a positive net social value to commit the offense. As a result, those individuals may be overdeterred. On the other hand, when it is optimal to prevent everybody from committing certain offenses (such as theft, rape or murder) then risk-aversion will not affect Becker's general conclusion.

The principle of maximum deterrence also figures prominently in the literature on incentives. If in a Principal/Agent relationship the principal can pay a cost and inspect ex-post the agent's choice of action, then it is optimal for him to impose the highest psosible penalty on agents found shirking. The Principal would thereby minimize inspection costs.[(2)]

Economists are generally unhappy with this result. First, the principle of maximum deterrence has been embodied only in a very limited way in most western legal systems, in which the counterthrusting principle that a punishment should fit the crime is the rule instead. The historical and social realities of western legal practice suggest that some important elements are missing in the analyses mentioned above. Second, in incentive theory, if the principle of maximum deterrence was taken seriously, then some of the most important incentive problems studied over the past twenty years could be solved trivially by allowing ex-post random inspection and imposing unbounded penalties on agents found shirking. The first-best outcome can then be approximated arbitrarily closely. To avoid this awkward conclusion, some authors have simply assumed that penalties are bounded (the size of the penalty cannot exceed some number, $0 < k < \infty$, and the agent's utility $U(k)$ is bounded below). This assumption has usually been justified by appealing to some form of limited liability (see Baiman-Demski (1980, a,b); Baron and Besanko (1984)). The first-best is then no longer attainable but notwithstanding the principle of maximum deterrence still holds, for these models usually give an optimal solution in which the optimal penalty is equal to the exogenously specified bound on penalties.

It has been argued (most notably by Stigler (1970) and Harris (1970)) that the risk of punishing an innocent individual may account for the apparent fact that maximum deterrence is not the most efficient policy of law enforcement. We propose to analyze this argument in greater detail, in the context of a Principal/Agent model. Our main and rather surprising conclusion is that even when the agent is risk-averse, an optimal contract may still impose maximum penalties on agents found shirking, despite the risk of punishing innocent agents. The point is, with maximum penalties the savings on inspection costs may actually outweigh the wage costs the Principal faces in offering a riskier wage contract to the agent.

We also address the issue of commitment to an inspection policy. Most existing studies assume that the Principal can commit to a given probability of inspection. Although this may be a reasonable assumption when considering law enforcement, it may not be adequate in considering other environments. Our results are summarized in the table below as a function of the commitment possibilities of the Principal as well as the risks of making inspection errors, for that case in which penalties are unbounded.(3)

	Commitment	No Commitment
Inspection errors	Second-best Possibly maximum deterrence (see Prop. 4)	Second-best bounded penalties
No inspection errors	First-best Maximum deterrence	Second-best Maximum deterrence

II. Random Inspection With No Observation Errors

Consider the following contracting problem between two individuals. The Principal hires an Agent to perform a certain task. For any action, a, chosen by the Agent from his action set, A, there are n possible profit (or output) outcomes, $(q_1,\ldots,q_n)$ that occur with probability $(\pi_1(a),\ldots,\pi_n(a))$; where $\pi_i(a) > 0$, for all i and $\sum_{i=1}^{n} \pi_i(a) = 1$. Usually one assumes that the principal does not observe a, but that q_i is publicly known. Thus, he can make the payment to the agent contingent on the observation of output. Let t_i be the monetary transfer to the agent when the principal observes q_i.

The Agent's preferences are represented by a von Neumann-Morgenstern utility function $U(t,a)$, which is assumed to be separable in income and actions: $U(t,a) \equiv V(t) - a$.(4) He is willing to work for the principal only if he gets a reservation utility, $\bar{U}$.

The principal is assumed to be risk-neutral for simplicity. Furthermore, it is assumed that the Agent's utility function, his action set and the function $\pi: A \to S$ (where $S = \{x \in R^n / x_i \geq 0$ and $\sum_{i=1}^{n} x_i = 1\})$ are common knowledge.(5)

Thus the Principal solves the standard program:

$$P_1 \begin{cases} \underset{\substack{t_i \in [\underline{t},\bar{t}] \\ a \in A}}{\text{Max}} & \sum_{i=1}^{n} \pi_i(a)\ (q_i - t_i) \\ \text{subject to:} & \\ \text{(IR)} & \sum_{i=1}^{n} \pi_i(a)\ V(t_i) - a \geq \bar{U} \\ \text{(IC)} & \sum_{i=1}^{n} \pi_i(a)\ V(t_i) - a \geq \sum_{i=1}^{n} \pi_i(\hat{a})\ V(t_i) - \hat{a} \\ & \text{for all } \hat{a} \text{ in } A\ . \end{cases}$$

We follow Grossman and Hart in assuming:

A.1: $V(\cdot)$ is continuous, concave and strictly increasing on the open interval $(\underline{t}, +\infty)$, where $\underline{t} > -\infty$, but $\lim_{t \to \underline{t}} V(t) = -\infty$

A.2: Let $M = \{v/v = V(t)$ for some $t \in (\underline{t}, +\infty)\}$. Then $(\bar{U}-a) \in M$, for all a in A.

The interpretation behind $\lim_{t \to \underline{t}} V(t) = -\infty$ is that the agent suffers an infinite loss, in utility, when all his wealth is taken away from him.

We shall modify the program P_1 slightly, by allowing the principal to inspect the agent's action, ex-post. We shall begin by assuming that he can observe the Agent's action exactly by paying an inspection cost $C > 0$. In the contract, the Principal must now specify a transfer to the agent when he inspects, which will be a function of his observation, $s(a)$; a transfer when he does not inspect, t_i ; and an inspection rule. This rule will in general be a function of the principal's output observation: for every outcome q_i the principal must specify a probability of inspection

$p_i \in [0,1]$. We assume, for the moment, that the principal can precommit himself to a given inspection policy.[6]

He now faces the following program:

$$
P_2 \left\{
\begin{array}{ll}
\underset{\substack{(t_i),\, s(a) \in (\underline{t}\ +\infty) \\ a \in A \\ p_i \in [0,1]}}{\text{Max}} & \sum_{i=1}^{n} \pi_i(a)\ \{(q_i - t_i)(1-p_i) + p_i(-C-s(a))\} \\
\text{subject to:} & \\
\text{(IR)} & \sum_{i=1}^{n} \pi_i(a)\ \{(1-p_i)V(t_i) + p_i V(s(a))\} - a \geq \bar{U} \\
\text{(IC)} & \sum_{i=1}^{n} \pi_i(\hat{a})\ \{(1-p_i)V(t_i) + p_i V(s(\hat{a}))\} - \hat{a} \leq \bar{U}\ , \\
 & \text{for all } \hat{a} \text{ in } A\ ,\ \hat{a} \neq a\ .
\end{array}
\right.
$$

It is immediate from the IC-constraint what the form of the optimal contract will be. Define a^* to be the first-best action and consider the worst case for the principal, where in the optimal contract all p_i are strictly positive. Then the principal can implement a^* and make all p_i arbitrarily small by letting $s(a)$ tend to $\underline{t}$ for all $a \neq a^*$ and setting $s(a^*) = t_i = V^{-1}(\bar{U}+a^*)$. Such a contract is incentive-compatible and satisfies the IR-constraint.

Moreover, this contract approximates the first-best outcome since the agent chooses a^* , is perfectly insured, and the expected inspection costs of the principal, $\sum_{i=1}^{n} \pi_i(a^*)\ p_i \cdot C$, are negligible.

(The above contract is optimal, a forteriori; when the principal can set some p_i equal to zero.) Of course, if the agent's utility function

was bounded below, the first–best would
not be approximated but the principle of maximum deterrence would still hold.

How is the optimal contract modified if we do not allow the principal to precommit to a given inspection policy? In the absence of commitment, the principal and the agent play a sequential game, where the timing of moves is illustrated below:

(1) contract signed:	(2) agent chooses	(3) occurrence of g_i	(4) principal chooses
$c=\{s(a);(t_i)\}$	$a \in A$		$p_i \in [0,1]$

Clearly, inspection by the principal will only be credible when g_i is observed, if he (weakly) prefers to inspect ex–post rather than not inspect. This is the case, for example, if

$$t_i \geq C + s(a) \tag{1}$$

where a is the action implemented by the contract. One immediate observation is that, if inspection takes place for some realizations of profit, g_i, then again the principle of maximum deterrence applies: to best induce the agent to choose action, a, an optimal contract sets $s(\hat{a})$ arbitrarily close to $\underline{t}$, for all $\hat{a} \neq a$. On the other hand, the first best outcome may no longer be approximated in general. For example, suppose that whenever the principal is indifferent between inspecting and not inspecting he inspects with probability one, then the first–best outcome will not be approximated (unless there exists an outcome which occurs with an arbitrarily small probability, $\pi_i(a)$). Of course, the principal could inspect with a smaller probability whenever he is indifferent. If he chooses a positive but arbitrarily small probability of inspection whenever he is indifferent then in fact the first–best might be approximated.

The first–best is approximated by setting $s(\hat{a})$ arbitrarily close to $\underline{t}$ for $\hat{a} \neq a^*$, letting the agent pay the cost of inspection (so that $s(a^*) = t_i - C$), and paying a non–inspection wage $t_i = V^{-1}(\overline{U} + a^*) + \varepsilon$. Where $\varepsilon > 0$, but ε can be made arbitrarily small by reducing the probability of inspection to an arbitrarily small number. However, there is no reason that the principal will pick the correct probability of inspection, ex–post, so that the first–best is by no means the only solution to this problem. To summarize, the main point of this section is that the principle of maximum deterrence holds whenever there is perfect monitoring, whether the principal can commit to an inspection policy or not.

III. RANDOM INSPECTION WITH TYPE–ONE AND TYPE–TWO ERRORS

In this section we investigate the case where the principal may only imperfectly observe the agent's action when he inspects. We shall proceed as follows: first we solve for the optimal contract in the simplest possible example. Then, whenever possible, we shall explain how our results are modified when the example is generalized.

In the simple example the agent's action set is given by $A = \{a_0, a_1\}$, where $a_0 < a_1$. That is, the agent can either work hard or slack. Furthermore, it is assumed that the principal cannot make the contract contingent on the output observation, q_i. The only information the principal obtains about the agent's action choice is the signal he observes when he inspects the agent. The second assumption is verified in situations where the principal must pay the agent before he observes q_i. For example, when the agent is a building constructor, the principal often finds out only 10 or 20 years after the completion of the building, what the quality of the construction is, but while construction is underway, he may randomly inspect the agent. This is the relevant example to consider if one is interested in law-enforcement issues.

Suppose now that the agent has chosen action a_i, $(i = 0,1)$; then the probability that the principal will observe action a_i when he inspects is strictly less than one:

$$\Pr(\tilde{a} = a_i / a_i) < 1 \quad ,$$

where $\tilde{a}$ is the signal observed by the principal. We define:

$$\beta_1 = \Pr(\tilde{a} = a_1 / a_1)$$

$$\beta_0 = \Pr(\tilde{a} = a_0 / a_0) \quad .$$

We assume that the principal can precommit to a given inspection policy, $P \in [0,1]$ and that β_1, β_0 are common knowledge. Also, for the contract to be enforceable by a court we must assume that the signal $\tilde{a}$ observed by the principal when he inspects is public knowledge.

Now when the principal offers a contract $c = \{t, s(a), P\}$ to the agent, the expected payoff of the agent when he chooses action a_1 and a_0

respectively is given by:

$$(2)\quad \begin{aligned} EU(c,a_1) &= (1-P)V(t) + P(\beta_1 V(s(a_1)) + (1-\beta_1)V(s(a_0))) - a_1 \\ EU(c,a_0) &= (1-P)V(t) + P(\beta_0 V(s(a_0)) + (1-\beta_0)V(s(a_1))) - a_0 \quad . \end{aligned}$$

For notational convenience, let $s(a_0) \equiv s_0$ and $s(a_1) \equiv s_1$.

We can restrict the analysis, without loss of generality to the case where $\beta_1 + \beta_0 > 1$.(7)

The incentive problem is real only if the principal optimally wants to implement a_1 . We shall assume that for any optimal contract it is best for the principal to implement a_1 . Now, the principal's problem is to choose t , s_1 , s_0 , and P to solve the program:

$$P_4 \begin{cases} \min\limits_{\substack{t,s_0,s_1 \varepsilon (\underline{t},+\infty) \\ P\varepsilon[0,1]}} & (1-P)t + P(\beta_1 s_1 + (1-\beta_1)s_0 + C) \\ \text{subject to:} & \\ \text{(IR)} & (1-P)V(t) + P[\beta_1 V(s_1) + (1-\beta_1)V(s_0)] \geq \bar{U} + a_1 \\ \text{(IC)} & P[V(s_1) - V(s_0)] \geq \dfrac{a_1 - a_0}{\beta_1 + \beta_0 - 1} \end{cases}$$

We shall solve P_4 in two stages. First we fix P and solve for the optimal transfers as functions of P : $\{t^*(P);\ s_1^*(P);\ s_0^*(P)\}$. Then we will determine the optimal probability of inspection, P .

When P is fixed we have a program that is equivalent to the cost-minimisation problem in Grossman and Hart (1983). As they noted P_4 is not a convex program; however, assumptions A1 and A2 permit us to regard $v \equiv V(t);\ v_1 \equiv V(s_1);\ v_0 = V(s_0)$ as the control variables of the principal. P_4 is then rewritten as:

$$P_5 \begin{cases} \min\limits_{\{v,v_0,v_1 \varepsilon M\}} & (1-P)h(v) + p(\beta_1 h(v_1)+(1-\beta_1)h(v_0)+C) \\ \text{subject to:} & \\ \text{(IR)} & (1-P)v + P(\beta_1 v_1+(1-\beta_1)v_0) \geq F \\ \text{(IC)} & P(v_1-v_0) \geq k \end{cases}$$

where $h \equiv V^{-1}(\cdot)$; $k = \dfrac{a_1-a_0}{\beta_1+\beta_0-1}$; $F = \bar{U} + a_1$.

P_5 involves the minimisation of a convex function ($h(\cdot)$ is convex since $V(\cdot)$ is concave) subject to two linear constraints and from Proposition 1 in Grossman-Hart (1983) we know that an optimal solution to P_5 exists. A solution must satisfy the first-order conditions and is such that (IR) and (IC) are binding. From the first-order conditions we obtain the following equation:

$$(3) \qquad h'(v) = \beta_1 h'(v_1) + (1-\beta_1)h'(v_0) \quad .$$

And from the (IC) and (IR) constraints and (3) we can solve for v , v_0 , v_1 to obtain:

$$(4) \qquad v_1 = \frac{F - v(1-P) + k(1-\beta_1)}{P}$$

$$(5) \qquad v_0 = \frac{F - v(1-P) - \beta_1 k}{P}$$

$$(6) \qquad h'(v) = \beta_1 h' \left[\frac{F-v(1-P)+k(1-\beta_1)}{P} \right] + (1-\beta_1)h' \left[\frac{F-\beta_1 k-(1-P)v}{P} \right]$$

<u>Proposition 1</u>: For any given $P \varepsilon (0,1]$ a unique solution v exists to (6).

Proof: The LHS of (6) is strictly increasing in v and the RHS is strictly decreasing in v. Furthermore, for any $P \varepsilon (0,1]$, for values of v close to $(F - \beta_1 k)$ the RHS of (6) is strictly greater than the LHS. Similarly, for v close to $F + (1-t_1)k$, the LHS is strictly greater than the RHS. It follows by the continuity of $h'(\cdot)$, that there must be a value v^* that satisfies (6) for any given $P \varepsilon (0,1]$. This value is unique since the LHS is strictly increasing in v and the RHS strictly decreasing in v, for any $P \varepsilon (0,1]$.

Thus equation (6) defines an implicit function $v = v(P)$, so that we can write the solutions to P_5 as functions of P: $v_1(P)$; $v_0(P)$ and $v(P)$.

For all $P \varepsilon (0,1]$ we have

a) $F + k(1-\beta_1) > v(P) > F - \beta_1 k$

This establishes a).

$$\lim_{P\to 0} h'\left(\frac{F + k(1-\beta_1) - (1-P)v(P)}{P}\right) = +\infty$$

unless, $\lim_{P\to 0} v(P) = F + k(1-\beta_1)$

(from a) we know that $v(P)$ cannot be greater than $F + k(1-\beta_1)$) ,

Similarly, $$\lim_{P\to 0} \frac{F - \beta_1 k - (1-P)v(P)}{P} = -\infty .$$

Now $h(\cdot)$ is strictly convex increasing; thus $h'(-\infty) > 0$ and $h'(+\infty) = +\infty$. It follows that (6) can only be satisfied for all values of $P \in (0,1]$ if we have:

$$\lim_{P\to 0} v(P) = F + k(1-\beta_1)$$

This establishes b).

It follows from proposition 2, that the first-best outcome cannot be approximated here, unless $\beta_1 = 1$, which we have ruled out. The reason is that

$$\lim_{P\to 0} h(v(P)) > h(F) = V^{-1}(\bar{U}+a_1)$$

In other words, in the second-best contract wage costs are higher for the principal. This is not surprising in view of the fact that the agent must be compensated here for the risk of being punished when he is inspected. Nalebuff and Scharfstein (1985) have obtained an equivalent result in a model of self-selection. They show that if the tests to which agents are submitted are not perfectly accurate, then the first-best cannot be approximated.

The second important conclusion to be drawn from proposition 2 is that as P tends to zero the transfer $h(v(p))$, to the agent when the principal does not inspect, does not become very large. Any optimal contract $c^* = \{v^*(P);\ v_1^*(P);\ v_0^*(P)\}$ must satisfy the equation:

$$h'(v^*(P)) = \beta_1 h'(v_1^*(P)) + (1-\beta_1)h'(v_0^*(P))$$

And proposition 2 tells us that

$$\lim_{P\to 0} h'(v^*(P)) = \lim_{P\to 0} \{\beta_1 h'(v_1^*(P)) + (1-\beta_1)h'(v_0^*(P))\}$$

$$= h'(F+k(1-\beta_1)) < +\infty$$

In other words, the expected wage, when inspection takes place, $\{\beta_1 \cdot h(v_1(P)) + (1-\beta_1)h(v_0(P))\}$, is bounded above as P tends to zero.

We are now ready to move to the second stage of the principal's minimisation problem:

$$\min_{P\varepsilon(0,1]} \quad (1-P)h(v(P)) + P\{\beta_1 h(v_1(P)) + (1-\beta_1)h(v_0(P))\} + P\cdot C$$

This can be rewritten as:

(8) $$\min_{P\varepsilon(0,1]} \quad \phi(P) + P\cdot C$$

And from (8) the following proposition follows:

<u>Proposition 3</u>: If the optimal probability of inspection is different from one, then it is a strictly decreasing function of the costs of inspection, C .

<u>Proof</u>: (9) $\phi(P_2^*) + P_2^*C_2 \leq \phi(P_1^*) + P_1^*C_2$

(10) $\phi(P_1^*) + P_1^*C_1 \leq \phi(P_2^*) + P_2^*C_1$

Adding (9) to (10) we obtain:

$$(P_1^* - P_2^*)\ (C_2 - C_1) \geq 0$$

but $(C_2 - C_1) < 0$, hence $P_1^* \leq P_2^*$.

Next, $\phi(\cdot)$ is differentiable and if there is an interior solution P^* to (8) (i.e., $P^* \neq 1$), such a solution must satisfy:

$$\phi'(P^*) = -C \quad .$$

It follows that if P_1^* and P_2^* are interior solutions, then $P_1^* < P_2^*$.

Proposition 3 tells us that the higher the inspection costs, the lower will be the probability of inspection. Thus one may wonder whether the optimal probability of inspection will be arbitrarily close to zero for some sufficiently high inspection cost. If this turns out to be indeed the case, then it follows that the principle of maximum deterrence would still hold (see the (IC) constraint in P_4). This would however be an uninteresting conclusion if it turns out that P is arbitrarily close to zero only if $C = +\infty$.

<u>Proposition 4</u>: If $\underline{t} > -\infty$, there exists $\bar{C} < +\infty$, such that if $C > \bar{C}$ a solution to $\min_{P \in (0,1]} \phi(P) + PC$ does not exist.

<u>Proof</u>: From proposition 2, we know that

$$\lim_{P \to 0} \phi(P) = h(F + k(1-\beta_1))$$

Next, by the envelope theorem we have:

$$\phi'(P) = \beta_1 h(v_1(P)) + (1-\beta_1) h(v_0(P)) - h(v(P))$$

so that $\lim_{P \to 0} \phi'(P) > -\infty$.

Given the above information about $\phi(P)$, we obtain the following figure:

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We know that $h(\cdot) > \underline{t}$ and by assumption $\underline{t} > -\infty$, it follows that $\phi'(P) > -\infty$ for all $P \in (0,1]$.

Now define $\bar{C}$ such that:

$$\inf_{P\in(0,1]} \phi'(P) = -\bar{C} \text{ , then } \bar{C} < +\infty \text{ .}$$

Also from proposition 3, if $C > \bar{C}$, we must have

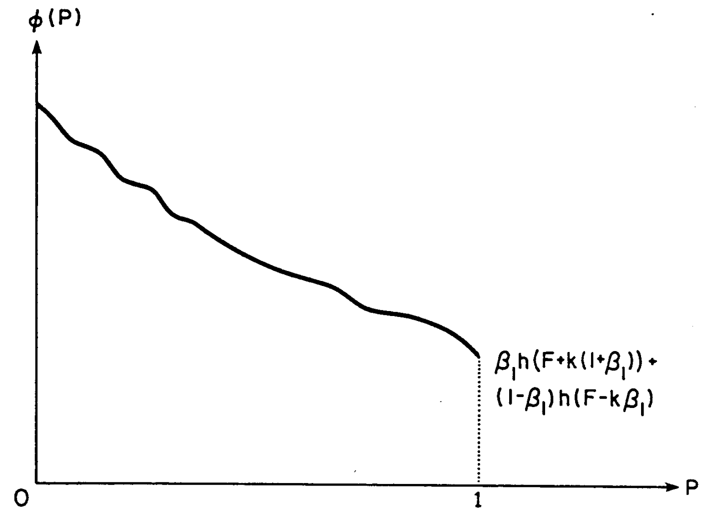
$$\phi'(P) = -C < \inf_{P\in(0,1]} \phi'(P) = -\bar{C} \text{ .}$$

This is clearly not possible, so that if $C > \bar{C}$, a solution to $\min_{P\in(0,1]} \phi(P) + PC$ does not exist.

In fact, for $C > \bar{C}$ we have an open-set problem similar to the one in section II. If the principal faces high fixed inspection costs, it may be optimal for him to inspect with probability P, arbitrarily close to zero.

There is a trade-off for the principal between facing high inspection costs, PC, or facing high expected wage costs, $\phi(P)$. If he lowers the probability of inspection, he must offer the agent a more risky inspection wage $\{\beta_1 h(v_1(p)) + (1-\beta_1)h(v_0(p))\}$, and since the agent is risk-averse this implies that he will have to pay the agent a higher expected wage. On the other hand, by lowering P, he lowers his expected inspection costs PC.

Now, as the variance of the inspection wage increases, the expected wage does not shoot off to infinity (this was established in proposition 2). The reason is that there are two counter-balancing effects, one of them dominating the other as P becomes small: on the one hand, the



$\phi(P)$
$\beta_1 h(F+k(1+\beta_1))+$
$(1-\beta_1)h(F-k\beta_1)$
O
1
P

increased risk due to a more variable inspection wage increases the expected inspection wage, but on the other hand, there is a reduction in risk due to a smaller probability of inspection. The latter effect dominates the former as P tends to zero.

Observe that our result would no longer be true if $\underline{t} = -\infty$, for then we have

$$\lim_{P \to 0} \phi'(P) = -\infty$$

and it would not be optimal for the principal to impose arbitrarily high penalties on the agent, unless $C = +\infty$. This point was also noticed by Nalebuff and Scharfstein (1985).(8)

So far we have not said anything about the type-one and type-two errors nor have we put restrictions on the degree of risk aversion (relative or absolute) of the agent. In this respect, proposition 4 is very general.

One may wonder how robust proposition 4 is to changes in the model. Note first that it does not depend on the size of the type-one and type-two errors. The form of the utility function of the agent, however, is important. For example, utility functions of the HARA-family, considered in Baiman-Demski (1980) will not do, mainly because they do not satisfy the condition that $V(\underline{t}) = -\infty$, for some $\underline{t} > -\infty$.(9)

Next, the restriction to two actions, $A = \{a_0, a_1\}$, does not appear to be important. This is a conjecture since we have not generalised proposition 4 to the case of n actions. A priori, there is no reason, however, for this result to break down when the agent has access to more than two actions.

More importantly, the assumption that the principal can precommit to a given inspection policy seems to be crucial to obtain proposition 4. Thus, in the example considered here, when the principal wants to implement a_1 and cannot precommit himself to a given inspection policy, the principle of maximum deterrence breaks down: With no commitment, we must have

$$t \geq \beta_1 s_1 + (1-\beta_1)s_0 + C$$

for inspection to take place, at all. At best, we have $t = \beta_1 s_1 + (1-\beta_1)s_0 + C$. Hence, no matter what probability of inspection the principal chooses, he will not be able to save on his inspection cost, C. But the main reason for increasing the size of the penalty was to save on expected inspection costs, $P \cdot C$. Now, the principal will not be able to save on costs and he will increase the expected wage he has to pay to the agent, by raising the penalty for shirking. Thus, in this case the principle of maximum deterrence breaks down.

To conclude this section we want to point out another interpretation of the model considered here. Suppose that by paying a sufficiently high inspection cost the principal can observe the agent's action choice perfectly accurately, when he inspects, but that the agent "trembles" slightly in his choice of action. Then $(1-\beta_1)$ would be the agent's choice-error when he wanted to choose action a_1, and $(1-\beta_0)$ his choice-error when he wanted to choose action a_0. Formally, this problem is identical to the one considered in this section, so that the conclusion would be that when the agent "trembles" this does not necessarily imply that penalties will be bounded in an optimal contract.

IV. Conclusion

The main purpose of this paper was to examine the claim that the principle of maximum deterrence would be violated when there is a positive probability of punishing someone who is innocent. The conclusion reached is that this is not necessarily true. Proposition 4 demonstrates that in some cases it may be optimal to punish an agent who shirks as severely as possible, even if there is a risk of punishing someone who is innocent. To reach this conclusion it was important to assume that the principal could precommit himself ex-ante to a given investigation policy. We explain that the combination of inspection errors and no-commitment possibilities for the principal is necessary in our model to obtain an outcome where penalties are bounded.

Proposition 4 is surprising and somewhat disappointing. It suggests that additional elements have to be taken into account if one wants to explain the structure of punishments in western legal systems. It seems clear that cultural and historical factors cannot be ignored. In particular, one potentially important explanation for the limited use of large penalties as a deterrence device is the reluctance of society as a whole to accept the possibility of severely punishing an innocent person. Society as a whole may prefer to spend more resources on law enforcement and thereby reduce both the likelihood of such an event and the size of the punishment imposed on an innocent person. This is no doubt only a partial explanation and there are probably deeper religious and cultural factors. However, the analysis of such factors is beyond the scope of this paper.

Footnotes

1. See also Townsend (1979); Polinsky and Shavell (1979); Gale and Hellwig (1985).

2. A number of authors have dealt with this problem in the context of adverse-selection models: See, for example, Stiglitz (1975); Townsend (1979); Guasch and Weiss (1980, 1981, 1983); Gale and Hellwig (1985); and Nalebuff and Scharfstein (1985).

3. The results can be extended in a straightforward fashion to the case where an exogenous bound on penalties is specified.

4. The results obtained here can be generalised to utility functions of a more general form: $U(t,a) = G(a) + K(a)V(I)$ (see Grossman and Hart (1983)).

5. It is now well known that the first-order approach to the Principal-Agent problem is unsatisfactory unless one is prepared to make severe assumptions about the distribution function over output (see Mirrlees (1974, 1975, 1979)). We did not want to restrict ourselves, at the outset, to special distribution functions, so we follow the approach by Grossman-Hart (1983).

6. One may ask what it means that the principal can precommit himself to a given probability of inspection p_i . The principal has a randomization device, which can be formalised as follows: Consider the interval $[a,b] \varepsilon R$, where $a < b$. Every time the device is activated it produces an outcome $\theta \varepsilon [a,b]$. Assume that θ is uniformly distributed on $[a,b]$. The principal determines a sub-interval $[a,b']$, (where $b' \varepsilon [a,b]$) when he chooses P_i .

That is, P_i is defined by:

$$P_i = \frac{b'-a}{b-a}$$

What is necessary for the principal to be able to commit himself to P_i , is that the randomisation device described above be public knowledge and that θ be publicly observable.

7. If $\beta_1 + \beta_0 < 1$ we can relabel our variables as $(1-\beta_1) = \hat{\beta}_1$ and $(1-\beta_0) = \hat{\beta}_0$ and we obtain $\hat{\beta}_1 + \hat{\beta}_0 > 1$.

8. Nalebuff and Scharfstein (1985) also show that if as $C \to +\infty$, the accuracy of the test becomes perfect (i.e., $\beta_1 \to 1$) then the first-best outcome can be approximated. This is also true in our model, since as $C \to +\infty$ and $\beta_1 \to 1$, we have $P^* \to 0$ and $\{\phi(P) + PC\} \to h(F) = V^{-1}(\bar{U}+a_1)$ (provided, of course, that $P \cdot C \to 0$). Moral-hazard models are quite different from self-selection models, and it is remarkable that, as far as optimal inspection (or testing) contracts are concerned, they yield identical conclusions.

9. $V(x)$ is a utility function belonging to the HARA family if:

$$V(x) = \frac{(1-\gamma)}{\gamma}\left(\frac{\beta x}{1-\gamma} + \eta\right)^{\gamma}$$

where $\gamma \neq 1$, $\beta > 0$; $\eta = 1$ if $\gamma = +\infty$.

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