Black Sheep or Scapegoats?

Implementable Monitoring Policies under Unobservable Levels of Misbehavior[*]

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Abstract

An authority delegates a monitoring task to an agent. It can only observe the number of detected offenders, but neither the monitoring intensity chosen by the agent nor the resulting level of misbehavior. We provide a necessary and sufficient condition for the implementability of monitoring policies. When several monitoring intensities lead to an observationally identical outcome, only the minimum of these can be implemented, which can lead to under-enforcement. A comparative statics analysis reveals that increasing the expected punishment can lead to less deterrence, since the maximal implementable monitoring intensity decreases. When the agent is strongly intrinsically motivated to curb crime, our results are mirrored and only high monitoring intensities can be implemented. Then, higher monetary rewards for detections lead to a lower monitoring intensity and to a higher level of misbehavior.

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1 Introduction

In many contexts of delegated monitoring, only detections but neither the underlying monitoring intensity nor the level of misbehavior can be observed. This leads to the problem that several monitoring intensities can lead to observationally identical outcomes, while the underlying degree of misbehavior differs strongly under these different monitoring intensities. As a result, looking only at detection statistics need not be informative about quality of monitoring.

For example, when a division head of a large company reports to cooperate headquarters a low number of violations against some corporate code of conduct for his division (e.g., compliance with certain ethical or safety standards), it is not obvious what this information reveals about the true level of misbehavior in the division. A low number of detections could either result from a strict monitoring policy leading to few offenders only, most of which are detected (*black sheep*). Instead, the monitoring policy could be lax, leading to a large number of offenders, out of which only few (*scapegoats*) are discovered. As a further example, in sports competitions it is hard to judge for outsiders what a given number of detected dopers reveals about the seriousness and intensity of anti-doping measures by the respective agencies and the virulence of doping among athletes. Further examples include victimless crime such as parking violations, prostitution, trafficking or drug dealing, where the number of detected offenders might not be too informative about the prevalence of an illegal activity.

The common feature of these examples is that an authority delegates the task of monitoring a population of individuals to an agent. Thereby, it is an outsider in the sense that it can neither observe the monitoring intensity chosen by the agent nor the resulting level of misbehavior.[1] In contrast, the potential offenders have a good assessment of the

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[1]The feature that several monitoring intensities lead to the same number of detections also applies to many further settings such as tax evasion, education or loan audits. However, as discussed in section 6 below, it is less clear in these contexts that the authority can be considered as an outsider who has to rely on the number of reported detections only.

probability of being detected, which is a standard assumption in the economic literature on enforcement (see e.g., the survey by Polinsky and Shavell, 2007).[2]

We develop a simple model which captures the interaction between the authority, the monitoring agent and potential offenders, and which builds on the previous literature on private law enforcement with a monopolistic enforcer who is rewarded on the basis of the number of detections (see e.g., Becker and Stigler, 1974; Landes and Posner, 1975; Polinsky, 1980; Besanko and Spulber, 1989; Garoupa and Klerman, 2002; Coşgel, Etkes, and Miceli, 2011).

Our analysis contributes to the literature on law enforcement and to the literature on delegated monitoring along several lines. First, we strengthen the argument already provided in Polinsky (1980) that high monitoring intensities might not be implementable because enforcers anticipate that strong deterrence reduces revenues. In particular, we provide a full characterization of implementable monitoring policies. Thus, we do not confine attention only to a particular monitoring policy which, for instance, maximizes social welfare (e.g., Polinsky, 1980) or some other objective function of the authority (Garoupa and Klerman, 2002). Intuitively, when several monitoring intensities give rise to the same number of detected offenses, then the agent can only be induced to choose the minimum of these.[3] Hence, under quite general conditions (for example, with respect to the underlying distribution of individuals' gains from the offense or the agent's effort cost function), a large set of monitoring policies (large ones, in particular) cannot be implemented by the authority, even if it had unlimited funds to reward the agent. This puts a lower bound on the crime rate which can be achieved in this setup.

Second, to evaluate the scope of this result, we perform a comparative statics analysis

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[2]As for the case of street prostitution, regular market participants might (correctly) perceive the actual threat of being arrested by the police (let alone conviction) to be much smaller than might be presumed by outsiders (see e.g., Levitt and Venkatesh, 2007).

[3]In Ichino and Muehlheusser (2008), a low monitoring intensity results as an optimal choice of the inspector as this allows him to elicit private information from the individuals.

both with respect to the distribution of gains from crime (where the previous literature has usually confined attention to the uniform case only) and the fine for detected offenders. Our results point to a novel trade-off between the severity of the expected punishment and the set of implementable monitoring intensities: on the one hand, when the expected punishment is relatively strong (for example, because there are not many individuals with sufficiently large gains from the offense, or because the fine is high), then the crime level tends to be low for any given monitoring intensity. But on the other hand, also the set of implementable monitoring intensities is small. We show that this latter effect may dominate, so that deterrence may in fact *decrease* as the expected punishment becomes more severe.

This result is in contrast to the standard approach in the enforcement literature in the tradition of Becker (1968) where the two components of expected punishment – the probability of detection and the fine – can be set independently from each each other. As a consequence, higher fines typically lead to more deterrence.[4] Moreover, the literature has provided various reasons against Becker's stark conclusion that fines should be set as large as possible. Examples include offenders who are risk averse or heterogeneous with respect to their wealth, offenders who engage in socially undesirable avoidance activities, costs of fine collection, or the requirement that the punishment should reflect the severity of the offense.[5] But also in these frameworks, higher fines would always lead to more deterrence. In contrast, our result suggests that in the context of delegated monitoring, even in the absence of all of these countervailing factors, optimal fines might not be too large because of the potentially detrimental effect on deterrence.[6] Importantly, the potentially inverse

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[4]Exceptions include a framework of juror behavior, in which high fines reduce the probability of conviction (Andreoni, 1991) and a framework of corruption, in which high fines increase the level of corruption (Kugler, Verdier, and Zenou, 2005).

[5]For a detailed discussion of these factors, see for example the survey by Polinsky and Shavell (2007) and the references cited therein.

[6]Note that this issue cannot be mitigated by replacing fines with imprisonment because our argument

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relationship between expected punishment and deterrence is not driven by behavioral biases or irrationality on the side of the offenders. Finally, the novel trade-off identified in our framework might also contribute to the difficulty of the empirical literature in providing robust evidence in favor of Becker's deterrence hypothesis, apart from the well-known methodological issues (see e.g. Levitt, 1997; Di Tella and Schargrodsky, 2004; Levitt and Miles, 2007).

Third, we consider a model extension where we allow the monitoring agent to be crime-sensitive in the sense that she directly benefits or suffers from criminal activity. In this respect, a disutility from crime can be naturally interpreted as resulting from intrinsic motivation to keep the crime level low.[7] We show first that when the agent's degree of intrinsic motivation is not too high, then, as in the baseline model, only relatively low monitoring intensities can be implemented (leading again to the same lower bound for the resulting crime level). In contrast, when the agent is strongly motivated to curb crime, a mirror results holds and only relatively high monitoring intensities can be implemented. This is in contrast to the previous literature on monopolistic enforcement which has confined attention to scenarios where over-enforcement is not an issue (see e.g., Polinsky, 1980; Garoupa and Klerman, 2002; Coşgel, Etkes, and Miceli, 2011). However, it might occur in cases when the harm from the offense is small or when the offender's cost of not committing it is large. One example in this respect would be minor parking offenses which are all deterred by an overly motivated agent. Moreover, intrinsic motivation to keep the crime level low yields an explanation for the phenomenon that there are (so many) inspectors who do monitor intensely, even if they would not suffer any material

holds for any type of punishment.

[7]In contrast, the previous literature has only considered indirect ways to induce the agent to internalize the effect of his monitoring choice on the resulting crime level. For example, Garoupa and Klerman (2002, p.131) discuss penalties for the agent which are increasing in the number of offenses which, however, would require that latter to be observable and verifiable. Consequently, instead of imposing penalties, Coşgel, Etkes, and Miceli (2011) argue in favor of allowing the monitoring agent to also collect income taxes (which are the higher, the lower the crime rate).

losses in case of shirking.

Fourth, depending on their degree of intrinsic motivation, agents react quite differently to incentive schemes, such as bounties for detected offenders as often analyzed in the literature (see e.g., Becker and Stigler, 1974; Landes and Posner, 1975; Polinsky, 1980; Besanko and Spulber, 1989; Garoupa and Klerman, 2002; Coşgel, Etkes, and Miceli, 2011). Intuitively, agents will generate more detections when they are rewarded for doing so independent of their intrinsic motivation. However, only for agents with weak intrinsic motivation, this amounts to increasing their monitoring intensity. In contrast, agents with a strong intrinsic motivation will *reduce* it as the reward increases in order to increase the number of detections, thereby also inducing a higher crime level. This latter result is similar to a crowding-out effect (see e.g., Deci, 1971; Deci, Koestner, and Ryan, 1999; Frey and Jegen, 2001; Gneezy, Meier, and Rey-Biel, 2011), but notice that here, monetary rewards do not directly impinge on the intrinsic motivation of the agent, for example in the sense of transforming an non-economic relationship into an economic one (Titmuss, 1970; Gneezy and Rustichini, 2000a,b). Rather, they simply introduce an incentive to generate more detections which requires a lower monitoring effort. Our analysis suggests a beneficial role of intrinsic motivation in remedying the problem of under-enforcement, but it also reveals the crucial importance of distinguishing between different types of enforcers in order to avoid severely misguided incentives.

The remainder of the paper is organized as follows: In section 2, we set up the baseline framework where the monitoring agent is not crime-sensitive. We then characterize implementable monitoring intensities in section 3. In section 4, we discuss the comparative statics properties of the baseline framework. In section 5, we study the case of a crime-sensitive monitoring agent. Section 6 discusses some implications from our analysis and concludes. All proofs are in the Appendix.

2 Model

There are three types of players: a population of *individuals* who are potential offenders, an *inspector* who monitors them, and an outside *governor* who incentivizes the inspector.

Individuals There is a unit mass of individuals who differ with respect to their gains from committing an offense, g_i, which are distributed according to a twice continuously differentiable cumulative distribution function $G : \mathbb{R} \to [0, 1]$. Following the tradition of Becker (1968), we assume that for a given probability of detection $p \in [0, 1]$, and a (exogenous) penalty $T > 0$, each individual will commit the offense if and only if its gain g_i exceeds the expected costs $p \cdot T$. This yields a threshold $\bar{g} := p \cdot T$, such that all individuals satisfying $g_i > \bar{g}$ ($g_i \leq \bar{g}$) will (not) commit the offense, which leads to a crime rate $F(p) := 1 - G(pT)$. We assume that the distribution of gains from crime g_i has full support on $[0, T]$ such that $F(p)$ is strictly decreasing.[8]

Inspector The inspector chooses the monitoring intensity $p \in [0, 1]$ which equals the probability each offender is detected with.[9] Monitoring is costly for the inspector, which is captured by a strictly increasing cost function $C(p)$. Taking into account the optimal behavior of individuals as characterized above, a monitoring intensity p gives rise to a number of detected offenders $D(p) := p \cdot F(p)$. Denote by $\Delta \subseteq [0, 1]$ the image of $D(p)$, that is, $\Delta := \{d \mid d = D(p) \text{ for some } p \in [0, 1]\}$, and by p^m the smallest monitoring intensity for which the number of detections is maximal. In special cases, this occurs at the upper boundary ($p^m = 1$), while otherwise, p^m is characterized by the first-order condition $D'(p^m) = 0$.

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[8]Note that this assumption does not rule out the possibility that there exist individuals with $g_i < 0$ or $g_i > T$.

[9]Alternatively, one could explicitly model the inspector's effort to affect the probability of detection through some (increasing) function. Under standard assumptions (e.g., Inada conditions), while adding notation, this approach would not affect our results qualitatively.

We study a context where the inspector can only be rewarded on the basis of the number of detections $D(p)$, which is observable. Denoting the monetary reward by $R(D(p))$, the inspector's payoff is[10]

$$u(p) = R(D(p)) - C(p). \tag{1}$$

Governor   The governor remunerates the inspector by setting a payment scheme $R(D(p))$, without being able to verify the inspector's actual behavior (p) or the crime level $(F(p))$.[11] For our purpose, it is not necessary to specify explicitly the preferences of the governor, for example, with regards to her distaste for crime. Rather, we assume that the governor aims at implementing some *desired* monitoring intensity $\hat{p}$. For instance, $\hat{p}$ could indeed be her privately optimal choice or, alternatively, the socially efficient level which results when taking into account the preferences of all involved individuals, including the harm and (possibly) the gains from the offense.[12]

3   Implementable Monitoring Policies

We now analyze under which circumstances the governor can successfully induce the inspector to choose $\hat{p}$, i.e. find payments R such that $\hat{p} \in \arg\max_p u(p)$. For any given level of detections $d \in \Delta$, define an ordered set of monitoring intensities $(P^d, <)$ such that each $p_l^d \in P^d$ satisfies $D(p_l^d) = d$. Importantly, while the number of detected offenses is equal to d for all $p_l^d \in P^d$, the underlying crime level is decreasing in l, while the inspector's effort costs are increasing in l, that is, for all $l = 1, 2, ...$ we have $F(p_l^d) \geq F(p_{l+1}^d)$ and

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[10]Additive separability of rewards and costs is assumed for analytical convenience only. The assumption that the inspector's utility is not directly affected by the crime level $F(p)$ is relaxed in section 5 below.

[11]See Garoupa and Klerman (2002) and Coşgel, Etkes, and Miceli (2011) for similar assumptions concerning the governor's role as an "outsider" in the sense of lacking these crucial pieces of information.

[12]In the literature, the gains from an offense are typically included in the social welfare function (see e.g., Polinsky and Shavell, 2007), but this is not an uncontroversial assumption (Stigler, 1970).
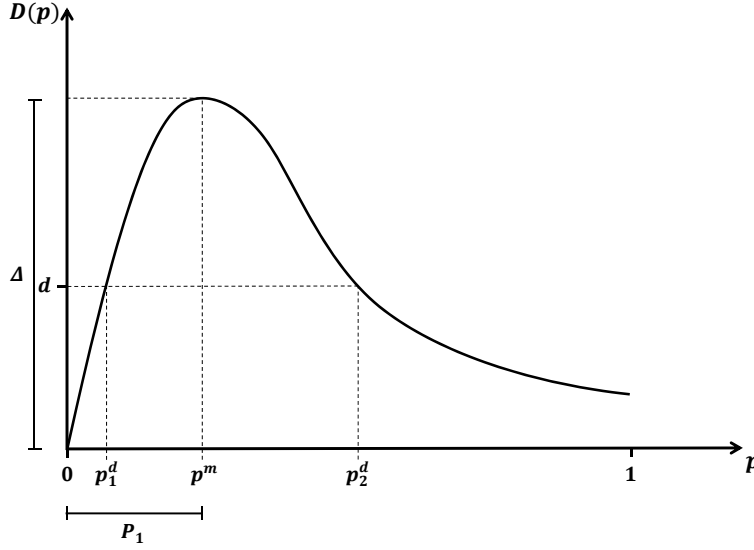
Figure 1: Number of detections as a function of monitoring intensity p

$C(p_l^d) < C(p_{l+1}^d)$, respectively. Denote by P_1 the set containing all minimum monitoring intensities, that is, $P_1 = \{p \mid p = p_1^d \text{ for some } d \in \Delta\}$.

Theorem 1. *A desired monitoring policy $\hat{p}$ is implementable if and only if $\hat{p} \in P_1$. The resulting set of implementable monitoring policies P_1 satisfies $P_1 \subseteq [0, p^m]$ such that the induced crime rate is at least $F(p^m)$.*

The result is illustrated in Figure 1. In special cases there is a unique monitoring intensity associated with a given number of (observable) detections such that implementability is not an issue.[13] Otherwise, when P^d is not a singleton, the inspector has a choice between several monitoring regimes in order to generate d detections. For example, he can either choose a low monitoring effort p_1^d (at low cost) which leads to a relatively high number of offenders, out of which d are detected (*scapegoats*). Alternatively, the inspector can choose a higher effort $p_2^d > p_1^d$ (at higher cost) which leads to fewer offenses, but again to d detections (this time better referred to as *black sheep*). Since the governor can observe

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[13]In the example depicted in Figure 1, this is true for the global maximum $D(p^m)$ and when the number of detections is very small.

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only the number of detections, but not the chosen monitoring intensity, these two effort choices are observationally identical from the governor's point of view. As the inspector's payment is the same for all $p_l^d \in P^d$, the inspector prefers to "deliver" any given number of detections $d \in \Delta$ at the lowest cost, and so his optimal choice is p_1^d. Consequently, only monitoring policies $p \in P_1$ can be implemented so that $\hat{p} \in P_1$ is a necessary condition for its implementation. As for sufficiency, all monitoring levels $\hat{p} \in P_1$ can be implemented by sufficiently rewarding the corresponding detection level $D(\hat{p})$, compared to all other detection levels $d \neq D(\hat{p})$.

In a next step, we analyze in more detail the set of implementable monitoring policies P_1. First, since Theorem 1 renders all $p > p^m$ non-implementable, the crime level is bounded from below by $F(p^m)$. Therefore, P_1's upper bound p^m becomes crucially important. The value of p^m is determined by the shape of the detection detection function $D(p)$, and its hump-shaped representation in Figure 1 is quite characteristic. To see this note that it always holds that $D(0) = 0$ and $D'(0) = F(0) > 0$ since without monitoring there are no detections (but a high crime level). Moreover, full monitoring typically also leads to few detections ($D(1) = 1 - G(T)$), because, given that every offense is detected, there are not many offenders (i.e., only those who are *undeterrable* as $g_i > T$). Thus, the maximal number of detections $D(p^m)$ is usually attained between these two extremes.

Second, even some $p < p^m$ might be non-implementable, in which case P_1 would be only a strict subset of the interval $[0, p^m]$. This case occurs when $D(p)$ is not monotonically increasing over this interval, such that there would exist several monitoring intensities leading to the same number of detections. By Theorem 1, only the minimum of these can be implemented. Otherwise, when $D(p)$ is monotonically increasing over $[0, p^m]$, we have $P_1 = [0, p^m]$ such that a monitoring intensity p is implementable if and only if $p \leq p^m$. The two properties discussed above – p^m interior and $D(p)$ monotonically increasing over $[0, p^m]$ – can be traced back to the distribution of gains from crime such that we get the following Corollary of Theorem 1.

Corollary 1. *For the set of implementable monitoring policies P_1 the following holds:*

(i) *Let the number of undeterrable individuals be sufficiently small such that it satisfies the condition $1 - G(T) < T \cdot G'(T)(> 0)$. Then p^m is interior with the consequence that not all monitoring policies are implementable, i.e. $P_1 \subsetneq [0, 1]$.*

(ii) *Let G be not too concave such that it satisfies the condition $G''(g) > -\frac{G'(g)}{g}(< 0)$ for $g \in [0, T]$. Then the number of detections $D(p)$ is monotonically increasing over $[0, p^m]$ with the consequence that a desired monitoring intensity $\hat{p}$ is implementable if and only if $\hat{p} \leq p^m$, i.e. $P_1 = [0, p^m]$.*

Corollary 1 provides two, arguably mild, conditions which are jointly sufficient for the detection function to be hump-shaped on its domain $[0, 1]$. Both statements of Corollary 1 are derived from the detection function $D(p) = p \cdot (1 - G(pT))$. Writing the first-order condition $D'(p) = 0$ as

$$1 - G(pT) = p \cdot T \cdot G'(pT) \tag{2}$$

reveals the two underlying marginal effects: The term on the left-hand side captures the higher number of detections as the monitoring intensity increases (for a given crime level). The term on the right-hand side measures the marginal deterrence effect (for a given probability of detection). Condition (i) of Corollary 1 ensures that there exists an interior monitoring intensity p that satisfies Eq. (2), i.e., that balances the two marginal effects. This is achieved by simply requiring that for $p = 1$ the marginal detection effect (left-hand side) is smaller than the marginal deterrence effect (right-hand side), which is never true for $p = 0$. Since by Theorem 1 only $p \leq p^m$ are implementable, under Condition (i) there exist monitoring intensities which are not.[14] Condition (ii) of Corollary 1 ensures that the right-hand side of Eq. (2) is increasing in p, that is, the marginal deterrence increases as monitoring becomes more and more intense.[15] Since the left-hand side of Eq. (2) is always

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[14]Polinsky (1980) provides further conditions which are sufficient for p^m interior such that monitoring policies close to 1 cannot be implemented.

[15]In fact, Condition (ii) even implies that $D(p)$ is concave. Together with Condition (i), which guarantees that p^m is interior, this ensures that $D(p)$ is hump-shaped on $[0, 1]$, similar to its illustration in

decreasing in p, when condition (ii) holds, then there is at most one monitoring intensity p that solves Eq. (2). This implies that the slope of the detection function changes its sign at most once (that is, turn from increasing to decreasing since $D'(0) = F(0) > 0$). Therefore, under Condition (ii), $D(p)$ must be monotonically increasing for $p < p^m$ and, hence, all of these monitoring intensities are implementable.

Remark. *Theorem 1 can also be expressed in terms of the elasticity of crime $\epsilon(p) := -F'(p)\frac{p}{F(p)}$. Under Conditions (i) and (ii) of Corollary 1 it is readily derived that $\epsilon(p) \geq 1$ if and only if $p \geq p^m$. Thus, as a rule, inspectors cannot be induced to choose a monitoring regime in the elastic range of the crime function.*

4 Comparative Statics Analysis

The implications from Theorem 1 depend strongly on the model fundamentals, in particular the underlying distribution of the gains from misbehavior G and the fine T. In this section we use comparative statics analysis to assess the impact of these two factors.

4.1 Impact of the Distribution of Gains From Crime G

Different distributions of gains from crime G give rise to varying levels of misbehavior, detections and implementable monitoring intensities. We compare distributions which differ in the sense of first-order stochastic dominance (FOSD). To this end, consider two distributions G and $\tilde{G}$ where G is first-order stochastically dominated by $\tilde{G}$, i.e. $G(g_i) \geq \tilde{G}(g_i)$ for all g_i, with the interpretation that $\tilde{G}$ has more probability mass on high gains from crime. Denote by $\tilde{p}^m$ and $\tilde{P}_1$ the respective maximizer of the number of detections and the set of implementable monitoring policies resulting under $\tilde{G}$.

Proposition 1. *Let G be first-order stochastically dominated by $\tilde{G}$.*

Figure 1.

(i) *Then, for any given monitoring intensity p, the number of detections and the level of misbehavior is larger under $\tilde{G}$ than under G.*

(ii) *Let G and $\tilde{G}$ satisfy Conditions (i) and (ii) of Corollary 1. If the slopes of $\tilde{G}$ and G at $p = p^m$ are not too distinct, then the set of implementable monitoring intensities is larger under $\tilde{G}$ than under G. Formally, if*

$$\tilde{G}'(p^m T) - G'(p^m T) < \frac{G(p^m T) - \tilde{G}(p^m T)}{p^m \cdot T} (\geq 0),$$
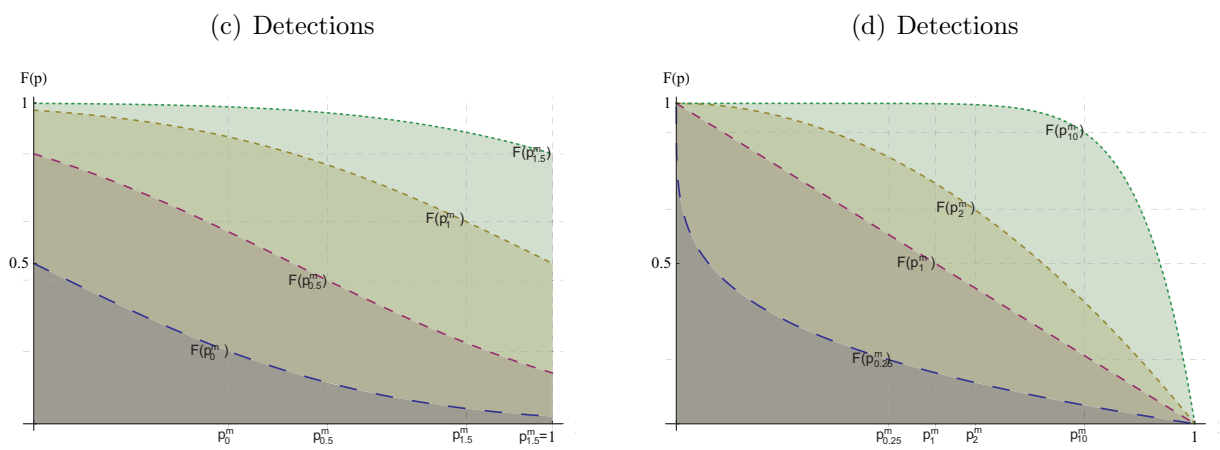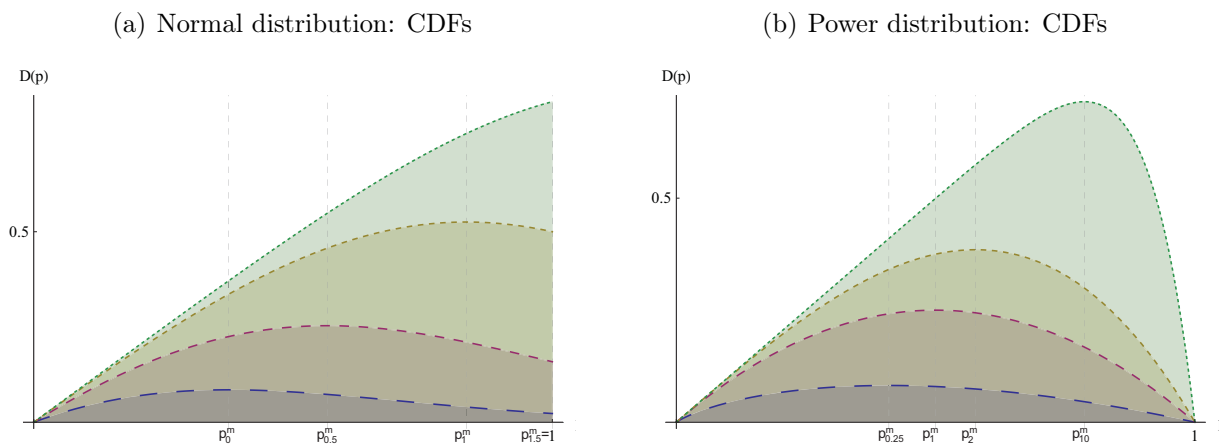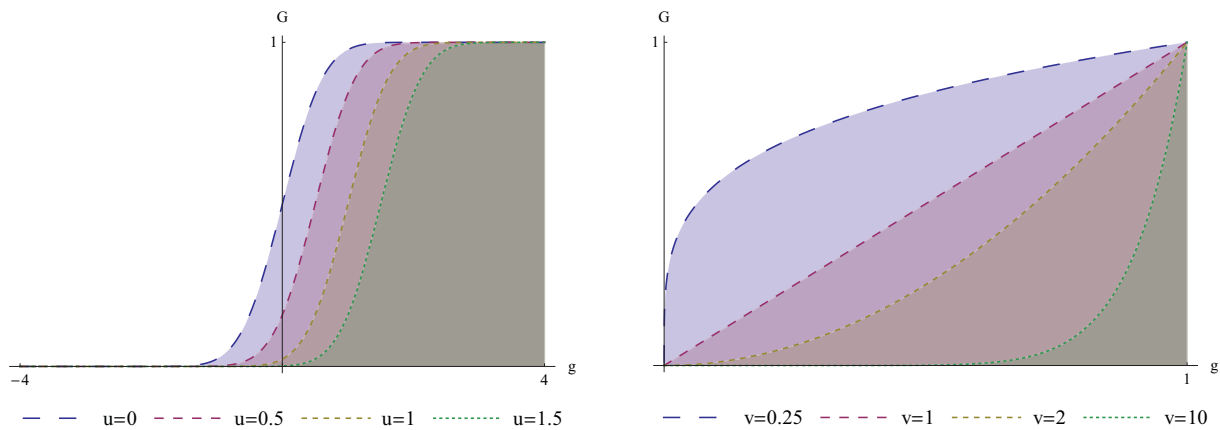
then $\tilde{p}^m > p^m$ and hence $\tilde{P}_1 \supsetneq P_1$.

The two parts of Proposition 1 suggest that there is a trade-off in the sense that facing a population with a low tendency toward misbehavior (as exemplified by distribution G) is on the one hand beneficial, as the level of misbehavior is relatively low for any given monitoring intensity p (part (i)). But on the other hand, only a small set of (low) monitoring intensities is implementable, which in turn might still lead to relatively high levels of misbehavior (part (ii)).

How these two effects unfold is illustrated by Figure 2 for two classes of distributions (and for $T = 1$): Normal distributions $N(\mu, 0.5)$ and Power distributions with cumulative distribution functions (CDFs) $G(g) = g^\nu$ (defined for $g \in [0, 1]$). In each row, the three panels of Figure 2 depict the CDF, the detection function $D(p)$, and the crime function $F(p)$ for the different parameter values, where those distributions with higher parameter values of μ and ν, respectively, first-order stochastically dominate those with lower values.

Panels (c) and (d) illustrate the trade-off as emerging from Proposition 1 above: When there is large probability mass on low realizations of g_i (low values of μ and ν), the overall levels of misbehavior and detections are low. But also the value p^m where the (hump-shaped) detection function $D(p)$ reaches its peak is small, so that, from Corollary 1, the set of implementable monitoring intensities $P_1 = [0, p^m]$ is relatively small.

Shifting probability mass to higher realizations of g_i (i.e. increasing μ and ν, respectively) then leads to upward shifts of both $F(p)$ and $D(p)$ since deterrence is now lower for

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(a) Normal distribution: CDFs

(b) Power distribution: CDFs

(c) Detections

(d) Detections

(e) Crime Level

(f) Crime Level

On the left and right we depict (for $T = 1$), respectively, the case where the gains from crime are distributed according to Normal distributions $N(\mu, 0.5)$ for $\mu \in \{0, 0.5, 1, 1.5\}$, and Power distributions with CDF $G = g^\nu$ defined on $[0, 1]$ for $\nu \in \{0.25, 1, 2, 10\}$. We also depict the respective values of p_μ^m and $F(p_\mu^m)$ (left), respectively, p_ν^m and $F(p_\nu^m)$ (right).

Figure 2: Illustrating Theorem 1 and Proposition 1 for different distributions

any level of p. As a result, p^m and hence also the upper bound of the set P_1 increases.[16] When there are sufficiently many individuals with large gains from the offense, $D(p)$ may even become monotonically increasing on $[0, 1]$ as in the upper graph in panel (c), so that $P_1 = [0, 1]$, thereby coinciding with the choice set of the inspector. In this case, Condition (i) of Corollary 1 is violated, i.e. there are many undeterrable individuals, and there is no loss in terms of non-implementable monitoring intensities, so that Theorem 1 has no bite.

Interestingly, with respect to the resulting minimum crime level $F(p^m)$, the "benefit" from a larger choice set P_1 due to a larger p^m can outweigh the "cost" in the form of an upward shift of the crime function $F(p)$. For example, for the case of the Normal distribution with the monotonically increasing detection function just discussed, there are many criminals who are not deterred even when monitored with the maximum feasible intensity $p = p^m = 1$ (see panels (c) and (e)). Therefore, the minimum crime level is $F(1) = 0.84$. In contrast, for the Power distributions considered, full deterrence is in principle possible as $F(1) \equiv 0$ for all $\nu > 0$ (see panel (f)). However, only monitoring intensities $p \in [0, p^m]$ where $p^m < 1$ are implementable (see panel (d)), so that the minimum crime level is $F(p^m)$, and it might well exceed the one under the monotone case: For example, for $\nu = 10$ (upper graph in panel (f)), we get $p^m = 0.78 < 1$, but $F(p^m) = 0.91 > 0.84$.

4.2 Varying the Fine T

To investigate the impact of changes of the exogenous fine T it is useful to now express explicitly, where appropriate, the dependency on T, i.e. we now write $F(p, T)$, $D(p, T)$ and $p^m(T)$, respectively. Analogously, to the comparative statics concerning the distribution

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[16]For example, consider the case $\nu = 1$ in the Power distribution, which corresponds to the uniform distribution of g_i over $[0, 1]$. Since $p^m = \frac{1}{2}$, the crime level is at least $F(p^m) = \frac{1}{2}$. Thus, when the governor wants to deter more than half of the population (for instance, because the harm from the offense is large), then the required monitoring policy $\hat{p} > \frac{1}{2}$ cannot be implemented.

G (embodied in Proposition 1), changes in the fine T have two countervailing effects on the set of implementable monitoring policies.

Proposition 2. *Consider two fines T and $\tilde{T}$ with $T < \tilde{T}$.*

(i) *For any given monitoring intensity $p > 0$, the number of detections and the level of misbehavior is smaller under $\tilde{T}$ than under T, i.e. $F(p, \tilde{T}) < F(p, T)$ and $D(p, \tilde{T}) < D(p, T)$.*

(ii) *Let G satisfy Conditions (i) and (ii) of Corollary 1. Then the set of implementable monitoring intensities is smaller under $\tilde{T}$ than under T. Formally, $\tilde{P}_1 \supsetneq P_1$ because $p^m(\tilde{T}) < p^m(T)$.*

Part (i) of Proposition 2 shows that an increase in T leads to a downward-shift of $F(p, T)$ and $D(p, T)$, thereby unambiguously lowering both the crime rate and the number of detections. Intuitively, for every given p, a higher fine increases the expected penalty from committing the offense, and hence leads to fewer offenses and, as a result, also fewer detections.

However, analogously to the comparative statics concerning the distribution G, part (ii) points to a countervailing effect in the sense that it leads to a smaller set of implementable monitoring intensities $P_1 = [0, p^m(T)]$. This result is in contrast to the celebrated finding of Becker (1968) according to which any expected fine $p \cdot T$ should be implemented with T as large as possible, as increasing T is costless (in contrast to increasing p being costly). For the contexts considered in our paper, this suggests that there is a reduced benefit associated with raising T in the form of a shrinking set of implementable monitoring intensities. This trade-off is illustrated in Figure 3 for the case where the gains from crime are distributed according to a standard Normal distribution $N(0, 1)$ for different levels of T. As can be seen in Figure 3, low values of T give rise to a large set of implementing monitoring intensities (i.e., $p^m(T)$ is large), but also the resulting crime level (and the number of detections) is high. A higher value of T reduces the crime level, but it also reduces the set of monitoring intensities that can be implemented by the governor. Which effect dominates depends on whether $p^m(T) \cdot T$ is increasing or decreasing

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in T, which in turn depends again on the underlying distribution G. Interestingly, in the example of the normal distribution depicted in Figure 3, the two effects just balance each other such that the minimum crime level $F(p^m(T), T)$ remains constant. For the case of power distributions this properties can even be shown analytically: That is, as long as $p^m(T)$ is interior, $F(p^m(T), T)$ is independent of T.[17] This implies that, in contrast to standard arguments, the minimum crime level cannot be reduced by an increase of the fine T.

5 Extension: Crime-Sensitive Inspectors
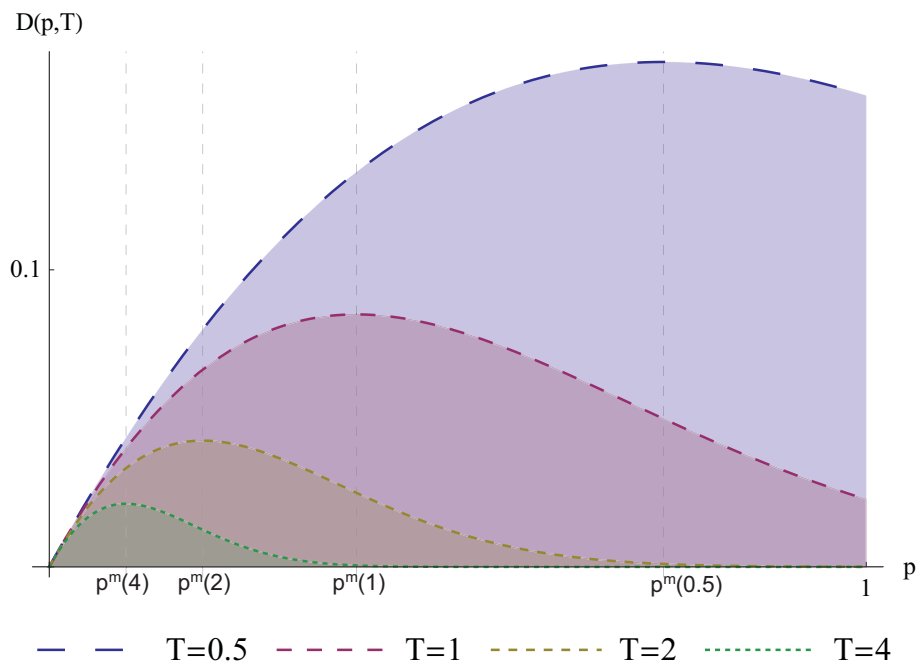
5.1 Implementable Monitoring Intensities

One major implication of our main result Theorem 1 is that inspectors cannot be induced to choose monitoring intensities beyond the ceiling p^m, which puts a lower bound $F(p^m)$ on the resulting crime level. We now investigate to which extent this result relies on the assumption maintained so far that inspectors only care about their remuneration and effort costs, but not about the level of crime itself (see Eq. (1)). In this section, we relax this assumption and allow for crime-sensitive inspectors, characterized by the more general utility function

$$u(p, \beta) = R(D(p)) - \beta F(p) - C(p), \tag{3}$$

where β measures how the inspector's utility is affected by the presence of crime. Thereby, disutility ($\beta > 0$) can be caused by intrinsic motivation to keep the crime level low, while benefits of crime ($\beta < 0$) can arise, for example, from accepting bribes.[18] The inspector's

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[17]Indeed, consider $F(p, T) = 1 - (p \cdot T)^\nu$ for $p \cdot T \leq 1$. Using the first order condition, we get $p^m(T) = \frac{1}{(\nu+1)^{\frac{1}{\nu}} \cdot T}$, which is interior given that $T > (1 + \nu)^{-\frac{1}{\nu}}$. Finally, $F(p^m(T), T) = 1 - (p^m(T))^\nu \cdot T^\nu = \frac{\nu}{1+\nu}$.

[18]The literature has discussed other reasons, why inspectors might worry about the prevailing crime rate, for example, payments which are inversely related to the crime level (Garoupa and Klerman, 2002) or

(a) Number of detections and implementable monitoring intensities
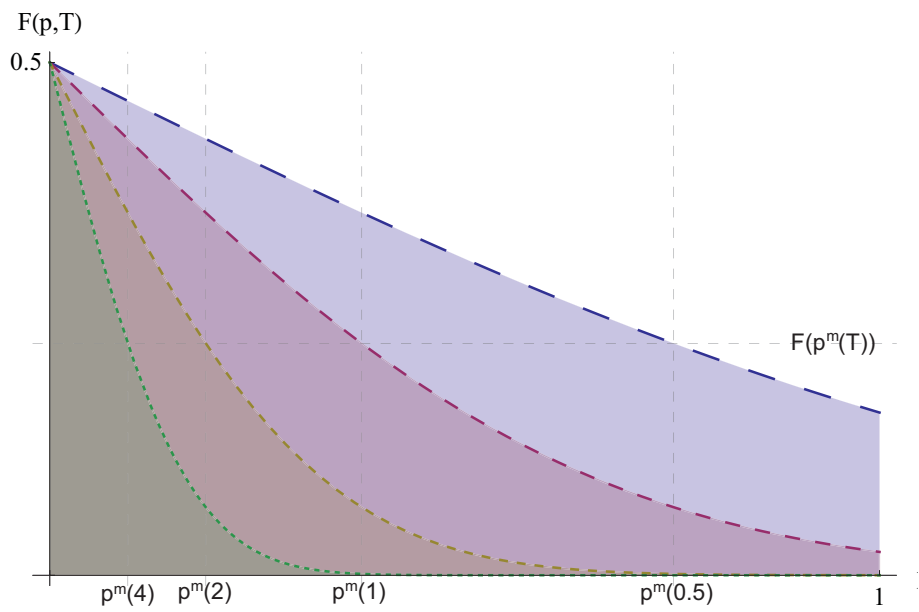
(b) Crime level

Gains from crime distributed uniformly on $[0,1]$ (special case of Power function $G = g^\nu$ for $\nu = 1$) for $T = 0.5, 0.75, 1, 1.5$.

Figure 3: The impact of changes in the fine T

preferences from the basic model are nested as the special case $\beta = 0$ in this more general utility function.

As will be shown, inspectors with a sufficiently strong intrinsic motivation can be induced to implement monitoring intensities ($p > p^m$), which are not implementable in the basic set-up. However, it turns out that for any type of inspector there is still a potentially large set of monitoring intensities which are not implementable.

To illustrate this point, we set $T = 1$ and consider quadratic costs of effort $C(p) = c \cdot p^2$ for some cost parameter $c > 0$. Moreover, for the sake of analytical tractability, we focus on case where the gains from the offense are uniformly distributed on $[0, 1]$ which corresponds to the special case $\nu = 1$ for the Power distributions as considered in Figure 2 above, leading to $F(p) = 1 - p$. The resulting detection function $D(p) = p \cdot (1 - p)$ is then hump-shaped and symmetric around $p^m = \frac{1}{2}$. Also the conditions of Corollary 1 are satisfied, so that the set of implementable monitoring intensities is $P_1 = [0, \frac{1}{2}]$ for an inspector who is not crime-sensitive ($\beta = 0$). The following result characterizes this set for crime-sensitive inspectors ($\beta \neq 0$):

Proposition 3. *Let the distribution of g_i be uniform on $[0, 1]$ and $T = 1$ such that $F(p) = 1 - p$ and $p^m = \frac{1}{2}$. Moreover, let the inspector's utility function be given by (3) with $C(p) = c \cdot p^2$. When the inspector's disutility from crime is sufficiently high (i.e. for $\beta > c$), then the set of implementable monitoring policies is $[\frac{1}{2}, 1]$. Otherwise (i.e. for $\beta < c$), it is given by $P_1 = [0, \frac{1}{2}]$.*

The underlying intuition for the proposition is simple: any reward offered for the desired number of detections $D(\hat{p})$ can also be gained with mimicking $\hat{p}$ by choosing $\tilde{p} = 1 - \hat{p}$ instead since $D(\tilde{p}) = D(p)$. It then depends on the inspector's sensitivity to crime β, in relation to the costs of monitoring, whether the higher or the lower monitoring

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a lower tax revenue part of which accruing to the enforcer (Coşgel, Etkes, and Miceli, 2011). In a different model framework, Besanko and Spulber (1989) assume that an inspector can allocate a given budget between enforcement and perquisites, so that the marginal rate of substitution can also be interpreted as a measure of the inspector's concern about crime.

	low monitoring intensity: $\hat{p} < p^m$	high m. intensity: $\hat{p} > p^m$
low motivation: $\beta < c$	(1) implementable	(2) under-enforcement!
high motivation: $\beta > c$	(3) over-enforcement!	(4) implementable

Table 1: Implementability by desired monitoring intensity and intrinsic motivation.

intensity is preferred. In the knife-edge case of $\beta = c$ the inspector is indifferent between each pair of monitoring intensities that lead to the same number of detections.

Proposition 3 suggests that inspectors can be distinguished with respect to their β-type as follows: For "bad" types ($\beta < c$), the intrinsic motivation for curbing crime is low, and we are back to the setting underlying Theorem 1, rendering monitoring intensities $p > p^m$ non-implementable. The resulting crime level tends to be high (i.e. larger than $F(p^m)$) and detected offenders should hence be classified as scapegoats.

In contrast, for "good types" ($\beta > c$), the intrinsic motivation is sufficiently high such that they can be induced to choose high monitoring intensities. In this case, the number of offenses is low and the detected offenders should rather be classified as black sheep. Notice, however, that in this case, a mirror result of Theorem 1 applies in the sense that only monitoring intensities $p \geq p^m$ can be implemented, but not lower ones.

This leads to the taxonomy presented in Table 1. When both the governor and the inspector prefer either a relatively high or a relatively low monitoring intensity, then non-implementability should not be a major issue for the governor. The situation changes when preferences diverge. In particular, when the governor prefers a much higher intensity than the inspector, then under-enforcement cannot be avoided. In the reverse case where the governor prefers a lower intensity than the inspector, non-implementability comes in the form of over-enforcement. In this respect, our analysis points to the crucial role of the "congruity" of the preferences of the governor and the inspector with respect to their preferred monitoring intensity.

In terms of this taxonomy, one could argue that the previous literature (see e.g., Polinsky, 1980; Garoupa and Klerman, 2002; Coşgel, Etkes, and Miceli, 2011) has confined

attention to the two upper cells in Table 1, while we also analyze the remaining two cases.[19] We consider both of the novel cases to be empirically relevant. Intrinsic motivation might be the explanation why in many situations where desired monitoring intensity is high (cell 4) there is no issue of implementability, although an inspector's shirking would not reduce his payments. And intrinsic motivation can cause over-enforcement when the governor's desired monitoring level is low (cell 3), e.g. in the case of minor offenses which are fully deterred by an overly motivated inspector. Note finally that our results, in contrast to parts of the literature, do not emphasize implementability issues within cells because these are (in principle) solvable by a different payment scheme.

5.2 Linear Reward Schemes

The inspector's degree of intrinsic motivation also crucially determines his behavioral response to changes in the reward scheme $R(D(p))$. We illustrate this effect by considering simple linear payment schemes where for each detection, the inspector receives a predefined reward or "bounty" r, i.e. $R(D(p)) = rD(p)$. This specification has also been employed in the previous literature on delegated (private) enforcement (see e.g., Becker and Stigler, 1974; Landes and Posner, 1975; Polinsky, 1980; Besanko and Spulber, 1989). The inspector's optimal monitoring policy $p^*(r, \beta)$ then satisfies

$$p^*(r, \beta) \in \arg \max_{p \in [0,1]} rD(p) - \beta F(p) - C(p).$$

Keeping the parameterizations of the previous section, this leads to the following result:

Proposition 4. *Let the distribution of g_i be uniform on $[0, 1]$ and $T = 1$ such that $F(p) = 1 - p$ and let the inspector's utility function be given by (3) with $C(p) = c \cdot p^2$, and let $R(D(p)) = rD(p)$. Then, for r not too small (i.e., $r \geq \max\{-\beta, \beta - 2c\}$),*

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[19]Indeed, Propositions 1 and 5 in Polinsky (1980) refer to cell (2); Garoupa and Klerman (2002) show that there is a linear reward scheme ("bounty") that implements a desired monitoring policy in cell (1), but not in cell (2); and Coşgel, Etkes, and Miceli (2011) introduce an inspector's crime-sensitivity by the right to collect taxes, but they do not explore the possibility that the disutility from crime is strong enough such that the lower cells (3) and (4) become relevant.

(i) the inspector's optimal monitoring policy is given by $p^*(r, \beta) = \frac{r+\beta}{2(r+c)}$, which is increasing in β.

(ii) an increase in the reward r leads bad (good) types to optimally choose a higher (lower) monitoring intensity, i.e. $\frac{\partial p^*(r,\beta)}{\partial r} > 0 \Leftrightarrow \beta < c$ and $\frac{\partial p^*(r,\beta)}{\partial r} < 0 \Leftrightarrow \beta > c$.

As for part (i), more intrinsic motivation to curb crime (β) leads to higher monitoring effort.[20] Thereby $p^*(r, \beta) > p^m = \frac{1}{2}$ if and only if $\beta > c$ so that each type optimally chooses indeed a monitoring intensity from the set of implementable ones as characterized in Proposition 3.

Part (ii) of the proposition reveals that the response of the two types of inspectors to changes in the bounty r are quite different: For bad types ($\beta < c$), starting at the lower bound $r = -\beta$ we have $p^*(r, \beta) = 0$, and the monitoring intensity increases as r increases, approaching $p^*(r, \beta) = \frac{1}{2}$ from the left in the limiting case $r \to \infty$.[21] In this case, higher monetary rewards have the standard effect of increasing monitoring intensity, generating more detections and thereby lowering the number of offenses.

In contrast, for good types ($\beta > c$), $p^*(r, \beta)$ is *decreasing* in reward r, starting at the lower bound $r = \beta - 2c$ where $p^*(r, \beta) = 1$ and approaching $p^*(r, \beta) = \frac{1}{2}$ from the right as r increases. Note that also these types respond with generating more detections when the marginal benefit r of doing so increases. However, they achieve more detections by *reducing* their monitoring intensity, which leads to more offenses. This result is in line with the literature on motivational crowding-out in the sense that the inspector's monitoring effort is the higher, the lower the strength of monetary incentives (see e.g. Deci, 1971; Deci, Koestner, and Ryan, 1999; Frey and Jegen, 2001; Gneezy, Meier, and Rey-Biel, 2011). In our framework, however, this effect is not due to the fact that such incentives directly reduce the inspector's degree of intrinsic motivation, for example, in the sense

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[20] Also in the framework of Coşgel, Etkes, and Miceli (2011), the inspector chooses a higher effort when he benefits from a lower crime rate in the form of a higher taxation income.

[21] This is shown formally at the end of the proof of Proposition 4, see also Garoupa and Klerman (2002).

of turning an non-economic relationship into an economic one (see e.g., Titmuss, 1970; Frey and Oberholzer-Gee, 1997; Gneezy and Rustichini, 2000b,a). Rather, for inspectors with a high degree of intrinsic motivation, generating more detections requires a lower monitoring effort, thereby also leading to more offenses.

The dependence of the inspector's response to monetary rewards on his degree of intrinsic motivation to keep the crime level low has further interesting consequences: For example, in order to implement some desired monitoring intensity $\hat{p} > \frac{1}{2}$, the corresponding bounty is $r^*(\hat{p}, \beta) = \frac{\beta - 2\hat{p}c}{2\hat{p} - 1}$ which is always positive when the inspector's intrinsic motivation is sufficiently strong (i.e., for $\beta > 2c$), but also $r^*(\hat{p}, \beta) < 0$ (i.e. a payment from the inspector to the governor for each detection) is possible. This occurs for good types with intermediate degrees of intrinsic motivation ($c < \beta < 2c$) and when $\hat{p} > p^*(0, \beta)$, that is, when $\hat{p}$ exceeds the monitoring intensity chosen by the inspector under intrinsic motivation alone ($r = 0$). In that case, the inspector needs to be punished by a negative bounty in order to increase his effort. Overall, our findings suggests that payment schemes based on the number of detections such as bounties are a delicate instrument, which is highly sensitive to the inspector's concern to keep the crime level low. In particular, ignoring an inspector's intrinsic motivation might lead to severely misguided incentives.

6 Discussion

In this paper, we contribute to the literature on delegated monitoring where only the number of detections, but neither the underlying monitoring intensity nor the level of misbehavior can be observed by the delegating authority (governor). This literature has pointed to a problem of under-enforcement in the sense that the first-best monitoring intensity need not be implementable. The reason is that when several monitoring intensities are observationally identical (i.e., give rise to the same number of detections), then the inspector to which the monitoring task is delegated can typically only be induced to choose the minimum of these. This also imposes a lower bound on the resulting crime level.

We first generalize the results from the previous literature and characterize the full set of implementable monitoring policies. We then perform a comparative statics analysis to study how the set of implementable monitoring intensities varies with changes in the fine and the distribution of gains from the offense. It turns out that the set of implementable monitoring policies is small for high fines or for low benefits from crime. In particular, the largest monitoring policy that is implementable decreases with the fine such that deterrence need not be increasing in the fine.

We then consider a model extension where the utility of inspectors is directly influenced by the number of offenses in the population. In this respect, we believe that the intrinsic motivation to keep the crime rate low is an empirically relevant (and so far neglected) factor. We first show that low levels of intrinsic motivation do not qualitatively affect the findings from the baseline model, and still only relatively low monitoring intensities can be implemented. However, when the degree of intrinsic motivation is sufficiently large, a mirror result prevails and the set of implementable policies is bounded from below (not form above). Consequently, either the desired monitoring policy is large enough to be implementable or over-enforcement occurs, that is, for any payment scheme the inspector will choose a monitoring intensity which is larger than the one which the governor wants to implement.

Our results also suggest that when inspector's are crime-sensitive (e.g., due to intrinsic motivation), then incentive schemes such as bounties as often discussed in the related literature might be an even more delicate instrument than was previously thought. The reason is that it crucially depends on the inspector's degree of intrinsic motivation whether such extrinsic incentives tend to reinforce the monitoring incentives generated by intrinsic motivation or crowd them out.

Our analysis, hence, points to the potentially crucial role of the degree of intrinsic motivation in the context of delegated monitoring which, however, will typically be often unobservable for governors. Therefore, an interesting model extension would be a screening framework where the governor can offer different pairs of monitoring intensities $p(\hat{\beta})$ and payments $R(\hat{\beta})$, depending on inspector's reported type $\hat{\beta}$ (which does not necessarily

coincide with his true type β). In contrast to standard screening models, the resulting design problem for the governor becomes significantly more intricate because of additional incentive constraints. This is due to the fundamental property of this setting that multiple monitoring intensities give rise to the same number of detections, which increases the scope of mimicking. A full analysis of such an extended screening framework is, however, beyond the scope of the present paper. From a more practical point of view, one possibility to learn about an inspector's intrinsic motivation over time would be to exploit the different comparative statics properties of agents with different degrees of intrinsic motivation. First, if it is possible to manipulate the costs of monitoring, then good types can be separated from bad types (since the number of detections increases in only one of the two cases). Second, if the the level of misbehavior adapts with some time lag to changes in monitoring intensity, types are revealed by increases of the monetary reward or by exchanging the inspector. Job rotation among monitoring agents would serve this purpose.

Finally, our analysis also sheds light on the question which contexts of delegated monitoring are more prone to issues such as under- or over-enforcement and the ensuing consequences. In this respect, note that our framework does not only apply to the arena of law & economics, but in principle also to other settings of monitoring such as enforcing safety and ethical standards in the manufacturing industry, or hygienic standards in the food industry. Another relevant context is education, where a school authority delegates the task of educating pupils to schools and teachers. In doing so, it is an outsider in the sense that it can typically only observe which grades are awarded (on average) in a school. However, it does not observe whether, for instance, good grades are due to the fact that the school, its teachers and the pupils are all hard-working or whether they are the result of a (tacit) agreement among these parties to take things easy. As a result, looking at grades only might not be too informative about the level of education of pupils, or the quality of schools. In this context, however, by featuring state- or nationwide tests which all pupils must take, it seems that authorities have successfully implemented institutional changes to ameliorate the problem that schools of different quality might be

observationally identical.[22] Even though such or similar measures might not always be available in the contexts to which our framework applies, our analysis nevertheless clearly points to the beneficial role of institutional changes which help authorities overcome their "outsider" status.

Appendix

A Proofs

A.1 Proof of Theorem 1

For $\hat{p} \notin P^1$ there is a $\tilde{p} \in P^1$ such that $D(\tilde{p}) = D(\hat{p})$ by definition of P^1. Noting, that $R(D(\tilde{p})) = R(D(\hat{p}))$ while $C(\tilde{p}) < C(\hat{p})$, it follows that $u(\tilde{p}) > u(\hat{p})$, which shows that $\hat{p}$ cannot be implemented. Now, suppose $\hat{p} \in P^1$. Let $R(d) = C(p_1^d) + \varepsilon$ if $d = \hat{d} := D(\hat{p})$ and $R(d) = 0$ otherwise. Then $u(\hat{p}) = \varepsilon > 0$, while for ε small enough we have $u(p) \leq 0$ for all $p \neq \hat{p}$ because other monitoring intensities $\tilde{p}$ that lead to the same number of detections (i.e. $\tilde{p} \in P^{\hat{d}}$) are associated with higher costs and all other choices (i.e. $p \notin P^{\hat{d}}$) do not lead to any reward.

For the second statement note that G continuous renders F continuous and thus D as well. Since $D(p)$ starts with $D(0) = 0$ and reaches its global maximum for the first time at p^m, $D(p)$ attains every value of its image Δ in the interval $[0, p^m]$. Thus, for any $d \in \Delta$, $p_1^d \in [0, p^m]$. $\qquad\square$

A.2 Proof of Proposition 1

Consider two distributions G and $\tilde{G}$ where G is first-order stochastically dominated by $\tilde{G}$, i.e. $G(g_i) \geq \tilde{G}(g_i)$ for all g_i. Denote by $\tilde{F}(p)$ and $\tilde{D}(p)$ the respective functions resulting

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[22]In Germany, for example, many states have recently introduced mandatory state-wide tests in German, English, and mathematics.

under $\tilde{G}$.

(i) For all $p \in [0,1]$, we have

$$F(p) = 1 - G(pT) \;\leq\; 1 - \tilde{G}(pT) = \tilde{F}(p) \quad \text{and}$$

$$D(p) = p \cdot (1 - G(pT)) \;\leq\; p \cdot (1 - \tilde{G}(pT)) = \tilde{D}(p).$$

(ii) Under Condition (i) of Corollary 1, p^m and $\tilde{p}^m$ are characterized by the first-order conditions $1 - G(pT) = p \cdot T \cdot G'(pT)$ and $1 - \tilde{G}(pT) = p \cdot T \cdot \tilde{G}'(pT)$. By Condition (ii) of Corollary 1, the right-hand sides of both equations are increasing in p. The left-hand sides of both equations are decreasing in p such that p^m and $\tilde{p}^m$ are the only intersections. This is illustrated in Figure 4 (while FOSD always implies that $1 - \tilde{G}(pT) \geq 1 - G(pT)$, the relation of the two right-hand sides is ambiguous). Observe that $\tilde{p}^m \geq p^m$ if and only if $1 - \tilde{G}(p^m T) \geq p^m \cdot T \cdot \tilde{G}'(p^m T)$.

The assumption $\tilde{G}'(p^m T) - G'(p^m T) < \frac{G(p^m T) - \tilde{G}(p^m T)}{p^m \cdot T}$ is equivalent to

$$1 - \tilde{G}(p^m T) > p^m \cdot T \cdot \tilde{G}'(p^m T) + \underbrace{(1 - G(p^m T)) - p^m \cdot T \cdot G'(p^m T)}_{=0} \qquad (4)$$

which yields the result.

$\square$

A.3 Proof of Proposition 2

To show the assertions for two fines T and $\tilde{T}$, we determine the slopes of the relevant functions.

(i) For all $p \in (0,1]$, we have

$$\frac{\partial F(p,T)}{\partial T} = -p \cdot G'(pT) < 0 \quad \text{and} \quad \frac{\partial D(p,T)}{\partial T} = -p^2 \cdot G'(pT) < 0.$$

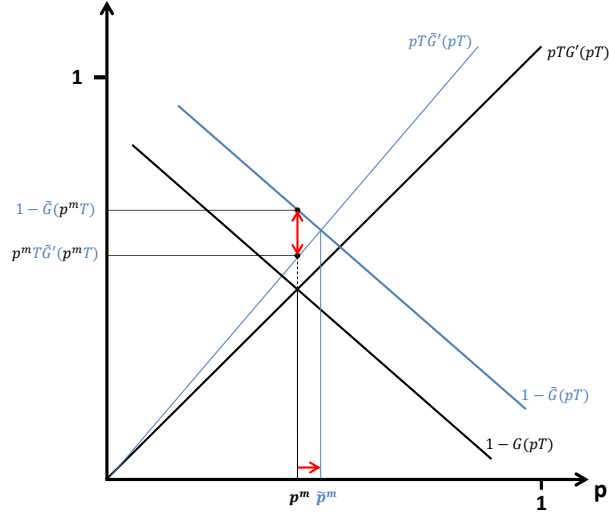(ii) By Condition (i) of Corollary 1, $p^m(T)$ is interior. Using the implicit function theorem, we have

Figure 4: The marginal deterrence effect and the marginal detection effect for two distributions G and $\tilde{G}$.

$$\frac{\partial p^m(T)}{\partial T} = -\frac{\frac{\partial^2 D(p,T)}{\partial p \partial T}}{\frac{\partial^2 D(p,T)}{\partial^2 p}} = -\frac{2p^m(T) \cdot G'(p^m(T)T) + p^m(T)^2 \cdot T \cdot G''(p^m(T)T)}{2T \cdot G'(p^m(T)T) + p^m(T) \cdot T^2 \cdot G''(p^m(T)T)}.$$

By Condition (ii) of Corollary 1, $D(p,T)$ is concave and thus the denominator is negative (this also follows from the second order condition for $p^m(T)$ to maximize $D(p,T)$). Observe that the negative sign of the denominator is equivalent to $G''(p^m(T)T) < \frac{-2G'(p^m(T)T)}{p^m(T) \cdot T}$ which is also equivalent to the numerator being negative. Taken together the expression is negative since the fraction after the minus sign is positive.

□

A.4   Proof of Proposition 3

For $C(p) = c \cdot p^2$ and $F(p) = 1-p$, the inspector's optimization problem is: $\max_p R(p(1-p)) - \beta \cdot (1-p) - c \cdot p^2$. Consider some desired monitoring intensity $\hat{p}$ and let $\tilde{p} := 1 - \hat{p}$. Noting that $R(\hat{p}(1-\hat{p})) = R(\tilde{p}(1-\tilde{p}))$, we get $u_i(\hat{p}) \geq u_i(\tilde{p})$ if and only if

$\beta \cdot (2\hat{p} - 1) \geq c \cdot (2\hat{p} - 1)$. For, $\beta > c$, $u_i(\hat{p}) > u_i(\tilde{p})$ if and only if $\hat{p} > \frac{1}{2}$ such that any preference intensity $\hat{p} < \frac{1}{2}$ is strictly worse than $\tilde{p} = 1 - \hat{p}$. Now, let $R(d) = x > \beta + c$ if $d = \hat{d} := D(\hat{p})$ and $R(d) = 0$ otherwise. Then choosing x large enough, e.g. $x = \beta + c$, yields $u(\hat{p}) = x - \beta \cdot (1 - \hat{p}) - c \cdot \hat{p}^2 > 0 - \beta \cdot (1 - p) - c \cdot p^2$ for any $p \neq \hat{p}, \tilde{p}$. The case $\beta < c$ is fully analogous. $\qquad\square$

A.5   Proof of Proposition 4

Suppose that the crime function is $F(p) = 1 - p$ and the inspector's utility is given by Eq. (3). If every detection is rewarded with some bounty r, the inspector's optimization problem becomes:

$$\max_{p \in [0,1]} r \cdot p(1 - p) - \beta \cdot (1 - p) - c \cdot p^2.$$

An interior solution is characterized by the first-order condition $p(r, \beta) = \frac{r + \beta}{2(r + c)}$, which is the first part of the proposition. The second part follows directly from

$$\frac{\partial p^*(r, \beta)}{\partial r} = \frac{c - \beta}{2(r + c)^2}$$

given, again, that the solution is interior.

An interior solution is obtained if $r \geq \max\{-c, -\beta, \beta - 2c\}$, where the first condition is equivalent to concavity of the maximization problem, while the second and the third condition assure that the function is increasing at the boundary $p = 0$ and decreasing at the boundary $p = 1$. To show that $r \geq \max\{-\beta, \beta - 2c\}$ is sufficient for an interior solution $p^*(r, \beta)$ and for the sake of completeness, we formally provide the optimal monitoring policies for all possible types.

1. For $\beta < c$ ("bad types"), we have $-\beta > -c > \beta - 2c$. Thus, the optimal behavior is:

$$p^*(r, \beta) = \begin{cases} \frac{r + \beta}{2(r + c)}, & \text{if } r \geq -\beta \\ 0, & \text{if } r < -\beta \end{cases}.$$

For $r = -\beta$ the inspector just chooses $p^* = 0$ and for growing r, $p^* = \frac{1}{2}$ is approached from the left.

2. For $\beta > c$ ("good types"), we have $\beta - 2c > -c > -\beta$. Thus, the optimal behavior is:

$$p^*(r, \beta) = \begin{cases} \frac{r+\beta}{2(r+c)}, & \text{if } r \geq \beta - 2c \\ 1, & \text{if } r < \beta - 2c \end{cases}.$$

For $r = \beta - 2c$ the inspector just chooses $p^* = 1$ and for growing r, $p^* = \frac{1}{2}$ is approached from the right.

3. For the "non-generic case" $\beta = c$, we have $-\beta = -c = \beta - 2c$. Then, the optimal behavior is:

$$p^*(r, \beta) = \begin{cases} \frac{r+\beta}{2(r+c)} = \frac{1}{2}, & \text{if } r > -\beta \\ \{0, 1\}, & \text{if } r < -\beta \\ [0, 1], & \text{if } r = -\beta \end{cases}.$$

For $r = -\beta$ the inspector is indifferent between all choices, for larger r he maximizes the number of detections, for smaller r he minimizes them.

$\square$

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