Making Corruption Harder:

Asymmetric Information, Collusion, and Crime*

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Abstract

We model the investigation of criminal activity as a principal-agent-monitor problem in which the agent can corrupt the monitor and side-contract to destroy evidence. Building on insights from Laffont and Martimort (1997) we study whether the principal can benefit from endogenously creating asymmetric information between the agent and the monitor. We show that the principal can benefit from randomizing the incentives given to the monitor (and letting those serve as the monitor's private information), but that the optimality of random incentives depends on pre-existing patterns of private information. We address the issue by providing a data-driven framework for policy evaluation that requires only unverified report data. A potential local policy change is an improvement if, everything else equal, it is associated with greater reports of crime.

KEYWORDS: monitoring, collusion, corruption, asymmetric information, random incentives, prior-free policy evaluation.

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1 Introduction

Agents potentially engaging in criminal behavior can undermine institutions by corrupting monitors in charge of investigating them. This paper explores the idea that corruption can be weakened by introducing endogenous asymmetric-information frictions between colluding parties. Building on seminal work by Laffont and Martimort (1997), we show that the cost of deterring crime can be reduced by randomizing the incentives given to the monitor, and letting the magnitude of those incentives serve as the monitor's private information vis-à-vis the agent. While potential efficiency gains can be significant, the optimality of random incentives depends on pre-existing patterns of asymmetric information. To facilitate policy design, we propose a data-driven framework for prior-free policy evaluation: although aggregate reports by monitors cannot be naïvely used to measure actual criminal activity, we show how to evaluate policy changes using unverified report data. The main takeaway is that a potential local policy change is an improvement if, everything else equal, it is associated with greater reports of crime.

We study a game between three players — a principal, an agent, and a monitor — in which the agent chooses whether or not to engage in criminal behavior $c \in \{0, 1\}$. The behavior of the agent is not observed by the principal, but is observed by a monitor who submits report $m \in \{0, 1\}$. We think of this report as evidence leading to prosecution: report $m = 1$ triggers an exogenous judiciary process which imposes a cost k on criminal agents; report $m = 0$ (which involves suppression of evidence whenever $c = 1$) triggers no such process. Although the principal cannot observe the agent's behavior, she can detect misreporting $m \neq c$ with probability q. The principal's only policy control is the efficiency wage w provided to the monitor.

We allow for collusion between the agent and the monitor at the reporting stage (i.e. corruption). In particular, the monitor can destroy evidence (report message $m = 0$) incriminating a criminal agent in exchange for a bribe. We think of the destruction of evidence as happening in front of the agent, so that there is no moral-hazard between the agent and the monitor. As a result, collusion boils down to a bilateral trading problem. Exploiting the classic insight that asymmetric information may prevent efficient trade and limits collusion (Myerson and Satterthwaite, 1983, Laffont and Martimort, 1997), we study the extent to which the principal can reduce the cost of incentive provision by creating endogenous asymmetric information between the agent and the monitor.

Our model fits a broad class of environments in which an uninformed principal is concerned about collusion between her monitor and the agents the monitor is supposed to investigate. This includes many of the settings that have been brought up in the empirical literature on corruption, for instance collusion between polluting firms and environmental inspectors (Duflo et al., 2013), tax-evaders and customs officers (Fisman and Wei, 2004), public works contractors and local officials (Olken, 2007), organized crime and police officers (Punch, 2009), and so on. In these settings the principal cannot efficiently monitor agents directly, but may realistically be able to detect tampered evidence by scrutinizing accounts, performing random rechecks in person, or obtaining tips from informed parties. Alternatively, the principal may be able to detect misreporting if crime has delayed but observable consequences, such as environmental pollution, public infrastructure failures, media scandals, and so on.

Our analysis emphasizes three sets of results. The first is that although deterministic incentive schemes are cheap in the absence of collusion, they can become excessively expensive once collusion is allowed. Efficient contracting between the agent and the monitor forces the principal to raise the monitor's wage to the point where the agent and the monitor's joint surplus from misreporting becomes negative. By using random incentives, the principal can reduce the rents of criminal agents, which lowers the cost of incentive provision. We make this point using a simple example without pre-existing asymmetric information. In this case, the cost-savings from using random rather than deterministic incentives are large, in excess of 50% under plausible parameter specifications.

Our second set of results qualifies these optimistic findings by considering environments with pre-existing asymmetric information. In addition to the incentives provided by the principal, the monitor experiences an exogenous privately-observed idiosyncratic cost $\eta \geq 0$ for accepting a bribe. We show that the optimality of random incentives depends on the convexity or concavity of the c.d.f. F_η of idiosyncratic costs η. If it is convex over a sufficiently large support, additional asymmetric information is counter-productive.

Finally, motivated by the fact that optimal policy depends crucially on fine details of the environment, we study the possibility of performing prior-free policy evaluations using reporting data from a population of agent-monitor pairs. We consider a principal who has limited knowledge about the parameters of the environment, and hence cannot infer levels of crime from reporting and misreporting data. We first show that aggregate reports of crime across different incentive schemes do not allow for reliable policy evaluation. Indeed, reports of crime depend on both underlying crime rates, and the monitors' decisions to report crime or not. As a result, it is possible that a new incentive scheme decreases aggregate reports of crime, while in fact increasing underlying crime rates. Nevertheless, we show it is possible to perform prior-free local policy evaluations using conditional report data from a single policy (i.e. average reports of crime conditional on realized incentives). Somewhat counter-intuitively, a local policy change improves on a reference incentive scheme if it is associated with higher rates of reported crime. This clarifies that naïvely inferring crime from reporting data leads to incorrect policy recommendations.

This paper and its companion, Chassang and Padró i Miquel (2016), both explore the idea that collusion may be addressed by exploiting informational frictions that make side-contracting difficult. The two papers consider different frictions and emphasize different policy channels. This paper focuses on asymmetric information between the monitor and the agent, and emphasizes endogenous bargaining failures. Chassang and Padró i Miquel (2016) focuses on moral hazard and emphasizes endogenous imperfect monitoring. It departs from the assumption that reports are contractible, so that the monitor is subject to moral hazard. The agent must incentivize her preferred report by committing to a retaliation strategy. To allow information transmission, the principal must limit the information content of her own response to the monitor's reports. Chassang and Padró i Miquel (2016) also attempts to address the question of policy evaluation. Under the requirement that data from several experiments is available, it shows how to obtain bounds on treatment effects using unverified reports.

On the applied side, this paper relates to and hopes to usefully complement the growing empirical literature on corruption. We address two aspects of the problem which have been emphasized in the literature, for instance in the recent survey by Olken and Pande (2012).[1] The first is that the effectiveness of incentive schemes may be very different over the short-run and the long-run: over time, agents will find ways to corrupt the investigators in charge of monitoring them. We explicitly take into account the possibility of collusion between agents and monitors and propose ways to reduce the cost it imposes on organizations. A second difficulty brought up by Olken and Pande (2012) is that reports of criminal behavior do not provide a reliable measure of underlying crime. Our structural model allows us to back-out measures of underlying crime using observed reports. This connects our work to a small set of papers on structural experiment design (see for instance Karlan and Zinman (2009), Ashraf et al. (2010), Chassang et al. (2012), Chassang and Padró i Miquel (2016), Berry et al. (2012)) that take guidance from structural models to design experiments whose outcome measures can be used to infer unobservable parameters of interest.

On the theory side, our work fits in the literature on collusion in mechanism design initiated by Tirole (1986). It is especially related to Laffont and Martimort (1997, 2000) and Che and Kim (2006, 2009), who emphasize the role of asymmetric information in limiting the extent of collusion.[2] Our contribution is two-fold. First, we show that the principal can potentially benefit from introducing endogenous asymmetric information through random incentives.[3] Second, as a step towards implementation, we show how to evaluate potential

[1] For recent work on the measurement of corruption, see Bertrand et al. (2007), and Olken (2007). See also the surveys by Banerjee et al. (2013) and Zitzewitz (2012).

[2] For more on the large literature on collusion in mechanism design, see Felli and Villa-Boas (2000), Faure-Grimaud et al. (2003), Mookherjee and Tsumagari (2004), Burguet and Che (2004), Pavlov (2008), Celik (2009) or Che et al. (2013).

[3] This relates our paper to a recent literature that studies optimal design of information structures; see, for instance, Bergemann and Pesendorfer (2007), Kamenica and Gentzkow (2011), Bergemann et al. (2015), Condorelli and Szentes (2016).

policy changes using only unverified reports. Also related is Baliga and Sjöström (1998), who suggest a distinct mechanism through which random wages (to the agent) may help reduce collusion. They consider a setting in which the agent has no resources of her own, so that any promised payment to the monitor must come from the wage she obtains from the principal. When that is the case, randomizing the agent's wages undermines her ability to commit to transfers.[4]

Other work has underlined the usefulness of random incentives for reasons unrelated to collusion. In Becker and Stigler (1974) random checks are an optimal response to non-convex monitoring costs. More recently, in work on police crackdowns, Eeckhout et al. (2010) show that in the presence of budget constraints, it may be optimal to provide high powered incentives to a fraction of a population of agents rather than weak incentives to the entire population.[5] In contrast to our analysis, incentives in Eeckhout et al. (2010) must be public information. High powered incentives are useful only if concerned agents are aware of them. In addition, Myerson (1986) and more recently Rahman (2012) emphasize the role of random messaging and random incentives in mechanisms, in particular in settings where the principal needs to disentangle the behavior of different parties.[6]

The paper is organized as follows. Section 2 introduces our framework. Section 3 studies a special case of our model with no pre-existing private information, and delineates the economic forces that make random incentives useful. Section 4 extends the analysis to environments with pre-existing asymmetric information, and shows that additional asymmetric information need not always be optimal. Section 5 proposes an approach to policy-evaluation

[4]Also relevant is the work of Basu (2011) and Basu et al. (2014) which highlights the value of asymmetric punishments as a way to make collusion more difficult.

[5]See Lazear (2006) for related results.

[6]Other papers have emphasized the role of random incentives. Rahman and Obara (2010) demonstrate that random messages can improve incentive provision in partnerships by allowing to identify innocent individuals. Jehiel (2012) shows that a principal may benefit from maintaining her agent uninformed about payoff relevant features of the environment, as this may induce higher effort at states at which she values effort most. In a multi-tasking setting, Ederer et al. (2013) show that random contracts may be effective in incentivizing the agent to take a balanced effort profile. In a monopoly pricing context, Calzolari and Pavan (2006a,b) show that a monopolist may benefit from selling to different types of buyers with different probabilities to increase the buyers' ability to extract revenue on a secondary market.

relying on naturally occurring report data. Section 6 — further developed in the Online Appendix — discusses several extensions to our model including: more sophisticated contracting between the principal and monitor, efficient incomplete-information bargaining between the monitor and agent, extortion from non-criminal agents, and settings in which monitor and agent interact before the agent chooses whether or not to engage in crime. Proofs are collected in Appendix A unless mentioned otherwise.

2 Framework

Players, actions, and payoffs. We consider a game with three players: a principal, an agent, and a monitor. The agent decides whether to engage in criminal behavior $c \in \{0, 1\}$, where crime $c = 1$ gives the agent a benefit $\pi_A > 0$ and comes at a cost $\pi_P < 0$ to the principal. Benefit $\pi_A > 0$ is the agent's private information, and is distributed according to a c.d.f. F_{π_A} with density f_{π_A} and support $[\underline{\pi}_A, \overline{\pi}_A]$.

The agent's action is not directly observable to the principal, but is observed by a monitor who chooses to make a report $m \in \{0, 1\}$ to the principal. We think of this report as evidence leading to prosecution: report $m = 1$ triggers a judiciary process that imposes an expected cost $k > \overline{\pi}_A$ on criminal agents and an expected cost $k_0 \in [0, k]$ on non-criminal agents. This judiciary process is exogenous and outside the control of the principal.

While reports can be falsified (i.e., the monitor can always send either report, regardless of the agent's action), we assume that the principal detects a false report $m \neq c$ with probability $q \in (0, 1)$, which makes reports partially verifiable. Detection may occur through several channels: for instance accounting discrepancies, random rechecks, or tips from informed parties. Criminal behavior may also have delayed but observable consequences, such as environmental pollution. We further assume that the principal is no longer able to punish a criminal agent after the monitor sends a falsified report $m = 0$: the evidence needed for prosecution is no longer available.

The monitor is paid according to a fixed wage contract with wage w, and gets fired in the event that the principal finds evidence of misreporting. The monitor is protected by limited liability and cannot be punished beyond the loss of wages.[7] In addition to her expected wage loss, the monitor incurs a cost $\eta \geq 0$ whenever she misreports. Cost η is the monitor's private information, and is distributed according to a c.d.f. F_η with density f_η.

As part of a possible side-contract, the agent can make transfers $\tau \geq 0$ to the monitor, i.e. pay her a bribe. Corruption occurs when the monitor accepts to destroy evidence for a criminal agent (i.e. sends message $m = 0$ although $c = 1$). We assume that crime, rather than corruption, is the behavior that the principal really cares about. Corruption undermines the effectiveness of institutions in charge of punishing crime.

Altogether, expected payoffs u_P, u_A, and u_M respectively accruing to the principal, the agent, and the monitor take the form:

$$\begin{aligned}
u_P &= \pi_P \times c \quad -\gamma_w \times w - \gamma_q \times q \\
u_A &= \pi_A \times c \qquad\qquad\qquad\qquad -[k \times c + k_0 \times (1-c)] \times m \quad -\tau \\
u_M &= w \qquad\qquad\qquad\qquad\qquad\quad -[q \times w + \eta] \times \mathbf{1}_{m \neq c} \qquad\quad +\tau,
\end{aligned}$$

where γ_w denotes the efficiency cost of raising promised wages and γ_q captures the principal's cost of attention. When the principal is operating under budget or attention constraints, these costs can be interpreted as shadow prices.

We emphasize that the monitor's incentives for truthful reporting are captured by the expected loss from misreporting $qw + \eta$. For ease of exposition we treat the distribution of wages w as the principal's policy variable. However, our analysis applies without change if scrutiny q is the relevant policy instrument.

Timing and Commitment. Our analysis contrasts the effectiveness of incentive schemes under *collusion* and *no-collusion*. The timing of actions is as follows.

1. The principal commits to a distribution of wages w with c.d.f. F_w, and draws a random

[7] The Online Appendix extends the analysis to the case where the principal and monitor can use arbitrary contracts.

wage w for the monitor, which is observed by the monitor but not by the agent.

2. The agent chooses whether or not to engage in crime $c \in \{0, 1\}$.

3. Under *collusion*, with probability λ the agent makes the monitor a take-it-or-leave-it bribe offer τ in exchange for sending message $m = 0$; with probability $1 - \lambda$ the monitor makes the take-it-or-leave-it bribe offer. We assume perfect commitment so that whenever monitor and agent come to an agreement, the monitor does send message $m = 0$. Under *no-collusion* nothing occurs.

4. Under *no-collusion* or, under *collusion* if there was no agreement in the previous stage, the monitor sends the message m maximizing her final payoff.

We assume for now that parameters k, k_0, λ and q are common knowledge. We relax this assumption in Section 5.

We think of non-collusive and collusive environments as respectively capturing short-run and long-run patterns of behavior. In the short run, the agent may take the monitors' behavior as given, and not explore the possibility of bribery. In the long run however, as the agent explores the different options available to her, she may learn that monitors respond favorably to bribes.

Population interpretation. Our model admits a natural population interpretation in which distributions F_η and F_{π_A} capture heterogeneity in the population of monitors and agents, and monitors and agents are matched independently. Under this interpretation, wage distribution F_w captures wage heterogeneity among monitors rather than the randomization of any monitor's wages.

Motivation. Our framework is intended to capture the challenges facing public agencies that rely on monitors to assess the behavior of regulated agents. For example, we can think of the principal as an environmental protection agency (EPA), the agent as an industrial plant, and the monitor as an investigator employed by the EPA. In this case, the industrial plant may choose to dump hazardous materials rather than incur the cost of processing them.[8] Besides environmental protection, other prominent examples include labor safety regulation, tax collection, health inspections, and tackling organized crime. In these cases, crime may respectively correspond to maintaining poor safety and health standards, fraudulent accounting, or extortion and smuggling. The monitor may commit not to report the agent by destroying, or simply by not collecting the evidence needed to initiate a judiciary process. Even if the monitor makes no report of crime, signals of misbehavior may be obtained by the principal after some delay: pollution or poor safety standards may lead to visible consequences (e.g. accidents, local contamination); civil society stakeholders may produce evidence of their own; aggrieved associates of the agent may volunteer incriminating information; and so on ...

Modeling assumptions and extensions. Some of our assumptions are critical to our results, for instance the fact that the principal can commit to a distribution of incentives across monitors, or that monitors cannot verifiably disclose their incentives to agents. We discuss the plausibility of these assumptions in Section 6.

Other assumptions affect the analysis, but do not ultimately change the general thrust of our message. We clarify these assumptions in Section 6 and, when possible, provide appropriate extensions in the Online Appendix. This includes extensions to environments in which bargaining occurs before the agent's crime decision; environments in which the principal can offer the monitor arbitrary contracts; settings in which the monitor and the agent can use arbitrary bargaining mechanisms; as well as environments in which the monitor can extort bribes from non-criminal agents.

[8]Note that in the US, environmental pollution is indeed subject to criminal prosecution. The EPA maintains a database of criminal cases resulting from its investigations at http://www2.epa.gov/enforcement/summary-criminal-prosecutions.

3 Random Wages in a Simple Case

We clarify the potential value of random wages using a simple version of our model in which all monitors have the same cost of falsifying information $\eta = 0$, and all agents get the same benefit $\pi_A < k$ from crime. We further assume that the agent has all the bargaining power at the side-contracting stage, and makes offers with probability $\lambda = 1$.

Under these assumptions, the expected cost that a monitor with wage w incurs from accepting a bribe from a criminal agent and sending a false report is qw. Thus, under *collusion*, a monitor with wage w accepts a bribe τ from a criminal agent if and only if $\tau > qw$.[9] Under *no-collusion*, or if the monitor rejects the agent's offer, the monitor's optimal continuation strategy is to send a truthful report $m = c$. In particular, the monitor cannot credibly commit to send report $m = 1$ when the agent is non-criminal. These observations imply that, under collusion, the expected payoff of a criminal agent of type π_A is $\pi_A - k + \max_\tau (k - \tau)\text{prob}(qw < \tau)$, and the expected payoff of a non-criminal agent is 0.

Deterministic wages. We begin by computing the cost of keeping the agent non-criminal when the principal can use only deterministic wages.

Lemma 1 (collusion and the cost of incentives)**.** *Assume that the principal uses only deterministic wages. Under* no-collusion *the principal can induce the agent to be non-criminal at 0 cost.*

Under collusion*, the minimum cost of wages needed to induce the agent to be non-criminal is equal to* $\frac{\pi_A}{q}$.

Proof. Given any wage w, under *no-collusion* the monitor's optimal strategy is to send a truthful report. The agent's payoff from action $c = 1$ is then $\pi_A - k < 0$ and her payoff from action $c = 0$ is 0. Thus, under *no-collusion* the principal can induce the agent to be non-criminal at zero cost.

[9] By convention, we assume that the monitor rejects the agent's offer whenever she is indifferent between accepting and rejecting a bribe.

Consider next a setting with *collusion*, and note that the monitor accepts a bribe τ from a criminal agent if and only if $\tau > qw$. The agent's payoff from taking $c = 1$ is therefore $\pi_A - \min\{k, qw\}$, while her payoff from action $c = 0$ is 0. It follows that the principal can induce the agent to take action $c = 0$ by setting a deterministic wage $w = \frac{\pi_A}{q}$. ■

Lemma 1 shows that, while deterministic incentive schemes work well under no-collusion, their effectiveness is significantly limited whenever collusion is a possibility. We now show that by randomizing wage w the principal reduces the efficiency of side-contracting between the agent and the monitor, and hence reduces the cost of incentive provision.

Proposition 1 (optimal incentives under collusion)**.** *Under* collusion*, the cost-minimizing wage distribution F_w^* that induces the agent to be non-criminal is described by*

$$\forall w \in [0, \pi_A/q], \quad F_w^*(w) = \frac{k - \pi_A}{k - qw}. \tag{1}$$

The corresponding cost of wages $W^*(\pi_A) \equiv \mathbb{E}_{F_w^*}[w]$ is

$$W^*(\pi_A) = \frac{\pi_A}{q}\left[1 - \frac{k - \pi_A}{\pi_A}\log\left(1 + \frac{\pi_A}{k - \pi_A}\right)\right] < \frac{\pi_A}{q} \times \frac{\pi_A}{k}. \tag{2}$$

The proof of Proposition 1 is instructive.

Proof. A wage distribution F_w induces the agent to be non-criminal if and only if, for every bribe offer $\tau \in [0, \pi_A]$, $\pi_A - k + (k - \tau)\text{prob}(\tau > qw) \leq 0$, or equivalently, if and only if, for every $\tau \in [0, \pi_A]$, $F_w\left(\frac{\tau}{q}\right) \leq \frac{k - \pi_A}{k - \tau}$. Using the change in variable $w = \frac{\tau}{q}$, we obtain that wage distribution F_w induces the agent to be non-criminal if and only if,

$$\forall w \in [0, \pi_A/q], \quad F_w(w) \leq \frac{k - \pi_A}{k - qw}. \tag{3}$$

By first-order stochastic dominance, it follows that in order to minimize expected wages, the optimal distribution must satisfy (3) with equality. This implies that the optimal wage distribution is described by (1). Expected cost expression (2) follows from integration and straightforward computations. ■

Further intuition for why random wages can improve on deterministic wages can be obtained by considering small perturbations around deterministic wage $\frac{\pi_A}{q}$. Wage $\frac{\pi_A}{q}$ deters crime since a criminal agent finds it optimal to offer bribe $\tau = \pi_A$, which absorbs all the potential profits from crime. Consider now setting a wage equal to $\frac{\pi_A}{q}$ with probability $1 - \epsilon$ and equal to zero otherwise. Since the cost k of prosecution is strictly higher than π_A, for $\epsilon > 0$ small enough, a criminal agent will still offer a bribe $\tau = \pi_A$. This lets the principal deter crime at a lower expected cost of incentives.

In this simple environment, the savings that can be obtained using random incentives are large: the cost of incentives goes from $\frac{\pi_A}{q}$ for deterministic mechanisms, to less than $\frac{\pi_A}{q}\frac{\pi_A}{k}$ for the optimal random incentive scheme. For instance, if the penalty for crime is greater than twice its benefits, i.e. $k \geq 2\pi_A$, the principal would be able to save more than 50% on the cost of wages by using random incentives. The gains remain large even if we consider simpler *binary* wage distributions.[10]

An example. Binary incentive distributions, boil down to establishing an elite class of harder-to-corrupt monitors. This relates the policies we study to the real-life use of "undercover tactics as a routine part of the inspection process" (Marx, 1992). In one example, *Operation Ampscam*, that took place in New York City, police agents posed as electrical installation inspectors, and arrested contractors who attempted to pay bribes in order to get poor-quality work approved. Undercover police inspectors play the role of hard-to-corrupt monitors in our model. Even if bribing police inspectors is possible, their presence reduces the payoffs of criminal agents by leaving them with two unattractive options. They can either make a high bribe offer that all monitors accept, or make a low bribe offer that undercover

[10]For the optimal binary wage distribution, the share of costs saved using random incentives is equal to $1 - \pi_A/k$. It puts probability $1 - \pi_A/k$ on $w = 0$ and probability π_A/k on $w = \pi_A/q$.

police inspectors reject. From the perspective of our model, the fact that Operation Ampscam led to arrests is consistent with the outcome in which criminal agents make low bribe offers that undercover police inspectors reject, and get punished with positive probability.

4 Pre-existing Asymmetric Information

Are random incentives robustly optimal? The efficiency gains from using random incentives are large in this simple example. Relaxing the assumptions of efficiency wages and take-it-or-leave-it-bargaining does not overturn the optimality of random incentives (see the Online Appendix). Pre-existing asymmetric information poses a more fundamental challenge. Indeed, it is intuitive that complete information should overstate the value of random incentives. Under complete information, random incentives are the only private information allowing the monitor to extract rents from criminal agents.

We return to the general model of Section 2. The monitor experiences a weakly positive private cost $\eta \sim F_\eta$ for falsifying information, and at the bargaining stage the agent makes the offer with probability λ and the monitor makes the offer with probability $1 - \lambda$. Given a distribution of wages F_w, a criminal agent of type π_A gets an expected payoff equal to

$$U_A(\pi_A) = \pi_A - k + \lambda \max_{\tau \in [0, \pi_A]} (k - \tau) \text{prob}(qw + \eta < \tau).$$

The expression above follows from two observations. First, a monitor with wage w and type η accepts bribe τ from a criminal agent if and only if $\tau > qw + \eta$. Second, a monitor demands bribe $\tau \geq k$ when she acts as proposer at the collusion stage and the agent is criminal, since k is the highest price criminal agents are willing to pay for a report $m = 0$.[11]

As in Section 3, a monitor's optimal continuation strategy is to send a truthful report $m = c$ if no agreement is reached at the collusion stage. This implies that non-criminal agents get a payoff equal to 0.

[11]Specifically, the monitor demands a bribe $\tau = k$ if $k \geq qw + \eta$, and a bribe $\tau > k$ (which she expects to be rejected) when $k < qw + \eta$.

Policy design under budget constraints. Given a distribution of wages F_w, an agent of type π_A will engage in crime if and only if $U_A(\pi_A) > 0$. Note that $U_A(\pi_A)$ is increasing in π_A, so that given a wage profile, agents follow a threshold strategy.

The principal's problem can be decomposed as follows. Given a target threshold π_A^*, find the cheapest wage distribution that implements this threshold. The global optimum can then be found by maximizing over the threshold π_A^*. Alternatively, we can consider the dual problem of a principal who operates under budget constraint $\mathbb{E}_{F_w}[w] = w_0$. Given a distribution of wages F_w, let us denote by $\overline{\pi}_A(F_w)$ the value of π_A for which an agent is indifferent between actions $c = 0$ and $c = 1$. Given budget w_0, the principal's problem is to find the distribution of wages F_w that maximizes threshold $\overline{\pi}_A(F_w)$ subject to $\mathbb{E}_{F_w}[w] = w_0$ — this is the *crime-minimizing* wage schedule, given budget w_0. The overall optimum can then be obtained by optimizing over budget w_0.

In what follows, we focus on the fixed budget version of the principal's problem. We emphasize that our population interpretation of the model means that the principal can satisfy budget constraint $\mathbb{E}_{F_w}[w] = w_0$ exactly while using a non-degenerate distribution of wages. The fixed-budget approach is appealing for additional reasons. First, it is realistic: organizations frequently operate within fixed budgets set by other decision-makers. Second, fixed budgets support the principal's ability to commit to mixed strategies. Indeed, taking agent behavior as given, the principal is indifferent over distributions $\tilde{F}_w$ satisfying $\mathbb{E}_{\tilde{F}_w}[w] = w_0$.

When is additional asymmetric information desirable? Under pre-existing private information, the optimality of random incentives depends on the shape of distribution F_η.

Definition 1. *We say that a wage profile with c.d.f. F_w is random if and only if the support of F_w contains at least two elements.*

Proposition 2 (ambiguous optimal policy). *(i) Whenever F_η is strictly concave over the range $[0, k]$, the crime-minimizing wage profile under any budget $w_0 > 0$ is random.*

(ii) Whenever F_η is strictly convex over the range $[0, k]$, the crime-minimizing wage profile under any budget $w_0 > 0$ is deterministic.

To get some intuition for this result, consider an agent's payoff from taking action $c = 1$:

$$\begin{aligned} U_A(\pi_A) &= \pi_A - k + \lambda \max_{\tau \in [0,\pi_A]} (k - \tau)\text{prob}(qw + \eta < \tau) \\ &= \pi_A - k + \lambda \max_{\tau \in [0,\pi_A]} (k - \tau)\mathbb{E}_{F_w}[F_\eta(\tau - qw)]. \end{aligned}$$

If F_η is strictly convex over the support of $\tau - qw$, a criminal agent is effectively risk-loving and she obtains a higher payoff from a random wage schedule than from a deterministic one with the same expectation. Inversely, if F_η is strictly concave over the support of $\tau - qw$, a criminal agent is effectively risk-averse and her payoff from a random wage schedule is smaller than her payoff from a deterministic one with the same expectation.

If F_η is neither concave nor convex over $[0, k]$ we can still provide sufficient conditions for random wage profiles to be optimal. Fix a deterministic wage $w_0 > 0$ and denote by τ_0 the highest solution to a criminal agent's optimal bribe problem when the monitor is compensated with a deterministic wage w_0,

$$\max_\tau (k - \tau)\text{prob}(qw_0 + \eta < \tau).$$

Proposition 3 (sufficient condition for random incentives)**.** *Whenever $\tau_0 \leq \frac{k}{2}$, the crime-minimizing policy given budget w_0 is random.*

If starting from a deterministic wage, the agent's optimal bribe is less than half the cost of prosecution, it is optimal to use random wages. The proof exploits the fact that c.d.f. F_η cannot be convex over arbitrarily large ranges of values.[12] The assumption that $\tau_0 \leq \frac{k}{2}$ lets us exploit non-convexities of F_η around w_0 to construct random wage schedules that improve

[12]Note that $\tau_0 \leq \frac{k}{2}$ implies that F_η is not convex over $[0, k]$. Indeed, optimal bribe τ_0 must satisfy the first-order condition $f_\eta(\tau_0 - qw_0)(k - \tau_0) = F_\eta(\tau_0 - qw_0)$. The convexity of F_η over $[0, k]$ implies that $F_\eta(\tau_0 - qw_0) \leq f_\eta(\tau_0 - qw_0)(\tau_0 - qw_0) < f_\eta(\tau_0 - qw_0)(k - \tau_0)$, where the last inequality uses $\tau_0 \leq \frac{k}{2}$ and $w_0 > 0$.

on fixed wages.

We note that when distribution F_η is log-concave, i.e. $\frac{F_\eta(\cdot)}{f_\eta(\cdot)}$ is increasing, optimal bribe τ_0 is increasing in w_0. As a result, the condition of Proposition 3 is more likely to hold when the principal's budget w_0 is small.

Because adding further asymmetric information does not necessarily improve incentive provision, correct policy design must depend on the restrictions, subjective or objective, that the principal can impose on the environment. However, specifying beliefs is often difficult for principals, which makes actual implementation difficult. To address the issue, we show in the next section that it is possible to perform prior-free policy evaluations using naturally occurring unverifiable report data.

5 Prior-free Policy Evaluation

We now show that it is possible to evaluate potential local policy changes using reports from monitors under sufficiently rich existing policies. The main takeaway is that marginal policy changes that, everything else equal, increase reports of crime, are local improvements. As a result, naïvely inferring crime from reporting data may lead to incorrect policy recommendations. This result echoes findings from Iyer et al. (2012). In a study of policy changes taking place in India in the early 1990s, the authors show that increased representation of women in local government led to increased reports of crimes against women, but reduced actual crime rates.

Naïve inference fails. We first show that a naïve use of reporting data from policy experiments fails to identify the effect that a change in policy has on crime rates.

Consider a principal who is operating under a budget constraint. Given budget $w_0 > 0$, let F_w^0 be the deterministic policy under which all monitors are paid wage w_0, and let F_w^1 be a non-degenerate wage distribution with $\mathbb{E}_{F_w^1}[w] = w_0$. We assume that wage policies

F_w^0 and F_w^1 are implemented over the same infinite population of exchangeable monitor and agent pairs. We are interested in whether reporting data under the two policies can identify which of them leads to lower crime.

For any policy decision $d \in \{0, 1\}$, denote by $\overline{C}_d$ the proportion of criminal agents under policy F_w^d. Let $\overline{R}_d$ be the fraction of monitors reporting $m = 1$ under policy F_w^d.[13]

Lemma 2 (unreliable aggregate reports)**.** *Consider any budget $w_0 > 0$, and any random incentive scheme F_w^1 such that $\mathbb{E}_{F_w^1}[w] = w_0$.*

The ordering of reports $\overline{R}_0$ and $\overline{R}_1$ is consistent with any ordering of crime $\overline{C}_0$ and $\overline{C}_1$: for any of the four possible pairs of orderings of reports and crime, i.e., $\overline{R}_0 \lesseqgtr \overline{R}_1$ and $\overline{C}_0 \lesseqgtr \overline{C}_1$, there exist specifications of k, F_{π_A} and F_η that lead to this ordering.

In words, the ordering of aggregate reports places no restrictions on the effect of random incentives on crime. Intuitively, reports of crime depend on both the underlying rate of crime and the monitors' decisions to report it. A change in incentive patterns from F_w^0 to F_w^1 changes both the agents' decisions to engage in crime and their bribing behavior. As a result, changes in aggregate reports from $\overline{R}_0$ to $\overline{R}_1$ do not always match changes in underlying crime.

Local policy evaluation. We now show that an appropriate use of report data from policies with non-degenerate wage distributions can be used to evaluate *local* policy changes. We emphasize three aspects of our results:

- The principal need not to know any of the parameters of the environment: the cost k imposed by the judiciary on criminal agents, the likelihood q of detection, and bargaining power λ need not be known.[14]

[13] More explicitly, let $\overline{\pi}_A(F_w^d)$ denote the type of an agent indifferent between actions $c = 0$ and $c = 1$ under policy F_w^d. Let τ_d be a criminal agent's optimal bribe under policy F_w^d. We have that $\overline{C}_d = 1 - F_{\pi_A}(\overline{\pi}_A(F_w^d))$ and $\overline{R}_d = (1 - F_{\pi_A}(\overline{\pi}_A(F_w^d))) \times \text{prob}_{F_w^d}(qw + \eta > \tau_d)$.

[14] These results contribute to a small literature on mechanism design with limited probabilistic sophistication. This includes maxmin optimal design (Hurwicz and Shapiro, 1978, Hartline and Roughgarden, 2008, Chassang, 2013, Frankel, 2014, Madarász and Prat, 2014, Prat, 2014, Carroll, 2013), as well as data-driven design (Segal, 2003, Chassang and Padró i Miquel, 2016, Brooks, 2014).

- Inference relies on the variation in wages already present in a non-degenerate policy, and does not require knowledge of equilibrium reporting data at the alternative policies.
- If the initial wage distribution is degenerate, a policy experiment is necessary to obtain reporting data for alternative wages. However, it is not necessary to wait for equilibrium crime rates and reports to adjust to the modified wage distribution in order to make policy inferences.

Take as given a non-degenerate wage distribution with cdf F_w^0 and density f_w^0. We think of distribution F_w^0 as the policy that the principal currently has in place. Let f_w^1 denote a density satisfying

$$\mathsf{supp}\, f_w^1 \subset \mathsf{supp}\, f_w^0 \quad \text{and} \quad \mathbb{E}_{f_w^0}[w] = \mathbb{E}_{f_w^1}[w]. \tag{4}$$

When current policy f_w^0 has full support over a range $[\underline{w}, \overline{w}]$, the set of policies f_w^1 satisfying (4) is the set of budget-neutral policies with support in $[\underline{w}, \overline{w}]$.

For any alternative policy f_w^1 and any $\epsilon \in [0, 1]$, construct the mixture $f_w^\epsilon = (1-\epsilon) f_w^0 + \epsilon f_w^1$. The proportion of criminal agents under policy f_w^ϵ is $\overline{C}_\epsilon = 1 - F_{\pi_A}(\overline{\pi}_A(f_w^\epsilon))$, where $\overline{\pi}_A(f_w^\epsilon)$ is the payoff-type of an agent indifferent between actions $c = 0$ and $c = 1$. We are interested in whether a principal can use reporting data to evaluate the effect that a local policy change in direction f_w^1 (i.e., a marginal increase in ϵ) has on the rate of crime.

Denote by $\nabla_{f_w^1} \overline{C}$ the gradient of equilibrium crime in policy direction f_w^1:

$$\nabla_{f_w^1} \overline{C} = \frac{\partial \overline{C}_\epsilon}{\partial \epsilon}\Big|_{\epsilon=0}.$$

With this notation, our goal is to evaluate the gradient of crime $\nabla_{f_w^1} \overline{C}$ for all directions f_w^1. A marginal move in the direction of f_w^1 is a local policy improvement whenever $\nabla_{f_w^1} \overline{C} < 0$.

As an example, suppose the initial policy f_w^0 has support $\{w_L, w_0, w_H\}$, with $w_L < w_0 < w_H$, and with most of its mass at wage w_0. Consider a principal who is interested in evaluating whether moving towards a policy with higher variance in incentives will lead to less crime. In this case, policy f_w^1 would be the budget-neutral policy with support $\{w_L, w_H\}$.

Let $\overline{R}_0$ denote the fraction of monitors reporting $m = 1$ under policy f_w^0. For any wage $w \in \mathsf{supp}\, f_w^0$, let $R(w|f_w^0)$ be the fraction of monitors with wage w reporting $m = 1$ under the current policy f_w^0; i.e., $R(w|f_w^0)$ is the share of monitors with wage w who are matched with a criminal agent and who reject equilibrium bribes under policy f_w^0.[15] For any policy f_w^1 such that $\mathsf{supp}\, f_w^1 \subset \mathsf{supp}\, f_w^0$ we can construct a counterfactual report of crime under wage distribution f_w^1, *keeping the agents' behavior constant*, as follows:

$$R_0(f_w^1) \equiv \mathbb{E}_{f_w^0}\left[R(w|f_w^0) \times \frac{f_w^1(w)}{f_w^0(w)}\right].$$

Counterfactual report $R_0(f_w^1)$ is the fraction of monitors that would report $m = 1$ if the principal were to change her policy to f_w^1 and agents continued to behave as if the policy in place was f_w^0. Counterfactual report $R_0(f_w^1)$ is obtained by re-weighting reports $R(w|f_w^0)$ and only requires data from policy f_w^0. The following result holds.

Proposition 4 (prior-free policy evaluation)**.** *There exists a fixed coefficient $\rho > 0$ such that for all alternative policies f_w^1,*

$$\nabla_{f_w^1}\overline{C} = \rho\left[\overline{R}_0 - R_0(f_w^1)\right].$$

This implies that a small movement from f_w^0 to f_w^1 will decrease crime ($\nabla_{f_w^1}\overline{C} < 0$) if and only if at policy f_w^0, the counterfactual report of crime reweighted for distribution f_w^1 increases. In other words, it is optimal to move towards the policy f_w^1 such that, everything else equal, would maximize the amount of reported crime. The proof is instructive.

Proof. For any policy f_w, let $\overline{\pi}_A(f_w)$ be the payoff-type of an agent indifferent between actions $c = 0$ and $c = 1$. Take as given an arbitrary policy f_w^1. Under wage schedule

[15] More explicitly, for all $w \in \mathsf{supp}\, f_w^0$, $R(w|f_w^0) = (1 - F_{\pi_A}(\overline{\pi}_A(f_w^0))) \times \text{prob}(qw + \eta < \tau_0)$, where $\overline{\pi}_A(f_w^0)$ is the cutoff agent type who is indifferent between $c = 0$ and $c = 1$ under policy f_w^0, and τ_0 is the optimal bribe under policy f_w^0.

$f_w^\epsilon = (1-\epsilon)f_w^0 + \epsilon f_w^1$, the agent's payoff $U_A^\epsilon(\pi_A)$ from action $c = 1$ is

$$U_A^\epsilon(\pi_A) = \pi_A - k + \lambda \max_\tau (k-\tau)\left[(1-\epsilon)\text{prob}_{f_w^0}(qw+\eta<\tau) + \epsilon\text{prob}_{f_w^1}(qw+\eta<\tau)\right].$$

Let τ_0 be the highest solution to this maximization problem for $\epsilon = 0$.

By the Envelope Theorem, $\forall \pi_A$,

$$\begin{aligned}
\frac{\partial U_A^\epsilon(\pi_A)}{\partial \epsilon}\Big|_{\epsilon=0} &= \lambda(k-\tau_0)\left[\text{prob}_{f_w^1}(qw+\eta<\tau_0) - \text{prob}_{f_w^0}(qw+\eta<\tau_0)\right] \\
&= \lambda(k-\tau_0)\frac{1}{1-F_{\pi_A}(\overline{\pi}_A(f_w^0))}\left[\overline{R}_0 - R_0(f_w^1)\right],
\end{aligned}$$

The second equality above follows from two observations. First, mean reports of crime $\overline{R}_0$ are equal to the product of baseline crime rates times the probability that equilibrium bribes are refused:

$$\overline{R}_0 = [1-F_{\pi_A}(\overline{\pi}_A(f_w^0))] \times [1-\text{prob}_{f_w^0}(qw+\eta<\tau_0)].$$

Second, for any $\tilde{w} \in \mathsf{supp}\, f_w^0$, mean reports $R(\tilde{w}|f_w^0)$ are equal to the product of baseline crime rates times the probability that a monitor with wage $\tilde{w}$ refuses the equilibrium bribe:

$$\begin{aligned}
\forall \tilde{w} \in \mathsf{supp}\, f_w^0, \quad R(\tilde{w}|f_w^0) &= [1-F_{\pi_A}(\overline{\pi}_A(f_w^0))] \times [1-\text{prob}(q\tilde{w}+\eta<\tau_0)] \\
\Rightarrow \quad R_0(f_w^1) &= [1-F_{\pi_A}(\overline{\pi}_A(f_w^0))] \times [1-\text{prob}_{f_w^1}(qw+\eta<\tau_0)].
\end{aligned}$$

Since $\overline{C}_\epsilon = \text{prob}_{F_{\pi_A}}(U^\epsilon(\pi_A) \geq 0) = 1 - F_{\pi_A}(\overline{\pi}_A(f_w^\epsilon))$, it follows that

$$\begin{aligned}
\nabla_{f_w^1}\overline{C} = \frac{\partial \overline{C}_\epsilon}{\partial \epsilon}\Big|_{\epsilon=0} &= f_{\pi_A}(\overline{\pi}_A(f_w^0))\frac{\partial U_A^\epsilon(\pi_A)}{\partial \epsilon}\Big|_{\epsilon=0} \\
&= \frac{f_{\pi_A}(\overline{\pi}_A(f_w^0))}{1-F_{\pi_A}(\overline{\pi}_A(f_w^0))}\lambda(k-\tau_0)\left[\overline{R}_0 - R_0(f_w^1)\right].
\end{aligned}$$

This proves Proposition 4. $\blacksquare$

Continuous policy improvement. The fact that local policy improvements can be identified with naturally occuring data authorizes a process of continuous policy improvement. Starting from a policy f_w^0, one can engage in gradient-descent by iteratively picking the direction for policy improvement f_w^1 that generates the largest counterfactual report of crime. Note that since accumulated policy-changes cease to be local changes, bribes and crime need to adjust to equilibrium before incremental policy assessments can be made: the process is necessarily gradual.

When F_η is strictly convex over $[0,k]$ this process pushes initial policy f_w^0 towards fixed deterministic wage w_0. Indeed, for any policy f_w^1,

$$\begin{aligned}\overline{R}_0 - R_0(f_w^1) &= [1 - F_{\pi_A}(\overline{\pi}_A(f_w^0))] \times [\text{prob}_{f_w^1}(qw+\eta<\tau_0) - \text{prob}_{f_w^0}(qw+\eta<\tau_0)] \\ &= [1 - F_{\pi_A}(\overline{\pi}_A(f_w^0))] \times [\mathbb{E}_{f_w^1}[F_\eta(\tau_0 - qw)] - \mathbb{E}_{f_w^0}[F_\eta(\tau_0 - qw)]].\end{aligned}$$

When F_η is strictly convex over $[0,k]$, counterfactual reports $R_0(f_w^1)$ are maximized by the distribution that puts all its mass point at w_0. Iterative policy improvement converges to the global policy optimum identified in Proposition 2.

We note that in more general settings, this process (if it converges) will lead to a local policy optimum, rather than a global policy optimum.

Experiments. Proposition 4 requires that the support of f_w^1 be included within the support of f_w^0. When this is not the case, one can obtain an experimental measure $R_0(f_w^1)$ by randomizing the wage of a small subset of monitors. The proof of Proposition 4 clarifies why one need not wait for equilibrium bribes and crime to adjust in order to interpret the data obtained from such an experiment. Under local policy changes, the equilibrium response of criminal agents has a second order effect on their payoffs. As a result, partial equilibrium responses are sufficient to assess changes in the expected payoffs of crime.

Evaluating other policy interventions. The logic of Proposition 4 extends to policy interventions that change truthful-reporting incentives $qw + \eta$ by affecting the distribution of preference parameter η rather than by changing wages w or scrutiny q. For instance, one may consider recruiting monitors from different pools hoping that they may be more or less pro-social. One may also be interested in the effect of a monitor-training, or a morale-enhancing program. In these cases, a local policy change corresponds respectively to marginally increasing the share of monitors recruited from a particular pool, or marginally increasing the share of monitors that undergo the training program. In all these cases, local policy changes towards interventions that yield more reports of crime are policy improvements.

Caveats. There are caveats to the policy recommendations following from Proposition 4. The assumptions needed for our results are that: 1) the policy change does not increase the returns π_A to crime; 2) the behavior of a monitor depends only on her *realized* incentives to report truthfully, $qw + \eta$.

Hence, Proposition 4 would not be affected if each monitor made an effort decision conditional on her realized incentives $qw + \eta$, but it would be affected if the overall policy changed the monitors' propensity to accept bribes. This could happen if monitors as a group found the use of random incentives unfair.[16] Alternatively, policy changes by the principal may cause spite among agents, effectively increasing the returns from crime. This is a concern explored in Iyer et al. (2012), that our framework does not address.

6 Discussion

We explored the idea that random incentives can limit the cost of corruption by making side-contracting between criminal agents and monitors more difficult. We show that while the optimality of random incentives depends on unobserved pre-existing patterns of private information, it is possible to use naturally occurring data to guide policy choice. A policy

[16] If this is the case, scrutiny q may be a more appropriate policy variable than wage w.

change is a local improvement if, everything else equal, it is associated with greater reports of crime. The logic of this result extends to policies that affect truthful-reporting incentives through preferences. Possible implementations of the policies we study are closely related to the use of undercover operations.

The remainder of this section discusses practical aspects of potential implementation as well as alternative modeling choices.

Commitment and disclosure. We assume that the principal can commit to a distribution of incentives across the population of monitors, and that monitors cannot disclose their incentives to agents. This is a natural assumption if heterogeneity in truth-telling incentives qw is created through heterogeneity in scrutiny q. Attention constraints mean that the principal will focus on a subset of monitors. Furthermore, being under scrutiny is unlikely to be part of a verifiable formal contract.

If wages w are the relevant policy dimension, commitment to a distribution of wages can be facilitated by first setting an aggregate budget, and then deciding how it should be assigned. This limits the principal's temptation to give all monitors a low wage. In view of the literature on relational contracting (Bull, 1987, Baker et al., 1994, 2002) it is plausible that aspects of compensation, such as promotion or bonuses may not be included in a verifiable contract, but left to the discretion of the principal. Of course greater reliance on the principal's discretion is not without costs, since it creates potential room for abuse on the principal's side.

Heterogenous incentives without random wages. The use of heterogeneous wages has distributional implications which stakeholders may find very unfair. This concern can be alleviated while still generating appropriate heterogeneity in incentives.

To the extent that the intensity of scrutiny q does not affect the welfare of the monitor when she reports truthfully, varying scrutiny q has limited distributional consequences for non-corrupt monitors. For this reason, it may be a more suitable policy instrument for practical implementation. Undercover police officers are indeed under much more scrutiny than regular city inspectors. More speculatively, in public infrastructure projects where, as in Olken (2007), local officials play the role of natural monitors, one could vary the probability with which the project gets audited.

Alternatively, one may be able to generate heterogenous incentives without randomization by letting the monitor's wage depend deterministically on data that is observable to the principal and the monitor, but not the agent. For instance, wages may be contingent on the monitor's tenure, diplomas, the number of crimes she has reported in the past, and so on. Such compensation schemes also introduce heterogeneity in the monitors' incentives, making side-contracting more difficult than under schemes that reward monitors with constant wages.

Ex ante bargaining. Our model assumes that the monitor and the agent side-contract after the agent chooses whether to engage in crime. This timing is reasonable in settings where interaction between the monitor and agent is short-lived. For instance, environmental and health inspectors may be rotated across a large number of sites.[17] However, in settings where agents and monitors repeatedly interact, the alternate timing, in which the agent and the monitor bargain before crime happens, may be more plausible.

We show in the Online Appendix that the results of Sections 3 and 4 extend qualitatively under this alternate timing. Endogenous asymmetric information can reduce the costs of incentive provision, but its value depends on pre-existing patterns of asymmetric information. Extending the policy evaluation results of Section 5 is more demanding. The difficulty is that when the monitor and the agent bargain ex ante, there is no report of crime in equilibrium. If they come to an agreement, crime occurs but is not reported. If they do not come to an agreement, crime does not occur. However, we show that reports of attempted corruption, rather than reports of crime, can also be used to evaluate policy. The message is qualitatively the same. Policy changes that increase reports of bribing attempts lower the equilibrium

[17]Reasons for rotation, as illustrated by Ohio's EPA 2014 staff rotation initiative, include fostering more homogeneous standards, as well as increasing inspectors' experience.

number of bribing attempts, and reduce the underlying crime rate.[18]

Extortion. Our model assumes that the monitor sends a subgame-perfect message following disagreement at the side-contracting stage. This implies that the monitor can never extract bribes from an agent which she observes to be non-criminal. As Olken and Pande (2012) highlight, this prediction is frequently violated: non-criminal agents often have to pay bribes. A simple variation of our baseline model accounts for this. Assume that when the monitor has the bargaining power, she is able to commit to the message she would send in the event of a bargaining failure. A monitor can then extract rents from an non-criminal agent by committing to report the agent as criminal unless a bribe is paid. While this changes the agent's incentives to engage in crime, we show in the Online Appendix that our main results continue to hold in this setting: random incentives may reduce the cost of corruption, and it is possible to perform local policy evaluation using reporting data.

Arbitrary contracting between the principal and the monitor. Throughout the paper we assumed that the monitor is compensated with a fixed wage contract w and gets fired if she is caught misreporting. Under this assumption, Section 3 shows that deterministic incentive schemes are expensive under collusion, and that the principal can significantly reduce the cost of deterring crime by randomizing the monitor's wage. These results continue to hold if the principal can use arbitrary contracts to compensate the monitor. With more sophisticated contracts, the principal can reduce the cost of deterring crime by offering the monitor a higher compensation whenever she sends report $m = 1$. Indeed, a high compensation following report $m = 1$ increases the agent's cost of bribing the monitor, and remains cheap for the principal because it tends to be paid off of the equilibrium path. However, the assumption that reports are only partially verifiable (i.e. false reports are only detected with probability q) limits the extent to which the principal can exploit such incentives. With par-

[18]Note that the specific results are different. While ranking the prevalence of bribery can be done using bribing-attempts data from a single policy, equilibrium data from two candidate policies is needed to rank crime rates. See the Online Appendix for details.

tially verifiable reports, as the monitor's compensation following message $m = 1$ gets large, it becomes optimal for her to report crime regardless of the agent's action. As a result, the cost of deterring crime with deterministic incentives remains high, and, as we show in the Online Appendix, the cost of keeping the agent non-criminal may be significantly reduced by using random incentives.

Signaling by the monitor. One concern with random incentives is that the monitor could signal her type. We address this issue in the Online Appendix by letting the agent and monitor use arbitrary bargaining mechanisms. Because monitors with low-powered incentives benefit from pooling with high-powered monitors, it is impossible for monitors to perfectly signal their types. As a result the principal still benefits from using random incentives.

Participation constraints. Throughout the paper we assume that the monitor is risk-neutral, so that randomness in wages does not make participation constraints more difficult to satisfy. Risk-aversion on the monitor's side may restrain the use of random wages, but our qualitative results continue to hold in that case. The reason for this is that under collusion, participation is not binding. Indeed, in Section 3 we show that the cost of keeping the agent non-criminal with deterministic incentives is equal to $\frac{\pi_A}{q}$, compared to an outside option of 0. This means that the principal can use random incentives without affecting the monitor's participation constraint.

Appendix

A Proofs

Proof of Proposition 2. The agent's payoff from taking action $c = 1$ is

$$\begin{aligned} U_A(\pi_A) &= \pi_A - k + \lambda \max_{\tau \in [0, \pi_A]} (k - \tau) \text{prob}(qw + \eta < \tau) \\ &= \pi_A - k + \lambda \max_{\tau \in [0, \pi_A]} (k - \tau) \mathbb{E}_{F_w}[F_\eta(\tau - qw)]. \end{aligned}$$

Consider first the case in which F_η is strictly concave over $[0,k]$. Let τ_0 be the highest solution to the optimal bribe problem under a deterministic wage w_0 (i.e., $\max_\tau (k-\tau)F_\eta(\tau - qw_0)$) and note that $\tau_0 > qw_0$. Let F_w be a random wage distribution with $\mathbb{E}_{F_w}[w] = w_0$ and support $[w_0-\gamma, w_0+\gamma]$, with $\gamma > 0$ small enough such that $\tau_0 > q(w_0+\gamma)$. For any $\epsilon \in [0,1]$, let $F_w^\epsilon = (1-\epsilon)\mathbf{1}_{w=w_0} + \epsilon F_w$; i.e., F_w^ϵ is the mixture between a deterministic wage w_0 and policy F_w. Since F_η is strictly concave over $[0,k]$, $(k-\tau)\mathbb{E}_{F_w^\epsilon}[F_\eta(\tau - qw)] < (k-\tau)F_\eta(\tau - qw_0)$ for all τ close to τ_0. For each $\epsilon \in [0,1]$, let τ_ϵ be the highest solution to $\max_\tau (k-\tau)\mathbb{E}_{F_w^\epsilon}[F_\eta(\tau - qw)]$. Since τ_ϵ is close to τ_0 for ϵ small, it follows that

$$(k-\tau_\epsilon)\mathbb{E}_{F_w^\epsilon}[F_\eta(\tau_\epsilon - qw)] < (k-\tau_\epsilon)F_\eta(\tau_\epsilon - qw_0) \leq (k-\tau_0)F_\eta(\tau_0 - qw_0),$$

where the last inequality follows since τ_0 solves $\max_\tau (k-\tau)F_\eta(\tau - qw_0)$. It follows that for ϵ small the expected payoff a criminal agent obtains under F_w^ϵ is strictly smaller than the one she obtains under the deterministic wage w_0.

Consider next the case in which F_η is strictly convex over $[0,k]$. Note that for any random wage distribution F_w with $\mathbb{E}_{F_w}[w] = w_0$, $F_\eta(\cdot)$ is convex over the support of $\tau - qw$ for all $\tau \in [0, \pi_A]$. Therefore, in this case the agent's payoff from being criminal under any random wage distribution with mean w_0 is larger than under the deterministic policy w_0. ■

Proof of Proposition 3. For $\Delta > 0$, consider the random wage $\tilde{w}_\epsilon$ defined by

$$\tilde{w}_\epsilon = \begin{cases} w_0 - \epsilon & \text{with proba} \quad \frac{\Delta}{\Delta+\epsilon} \\ w_0 + \Delta & \text{with proba} \quad \frac{\epsilon}{\Delta+\epsilon}. \end{cases}$$

The expected payoff of a criminal agent under random wage $\tilde{w}_\epsilon$ is

$$U_A(\pi_A|\tilde{w}_\epsilon) = \pi_A - k + \lambda \max_\tau (k-\tau)\text{prob}_{\tilde{w}_\epsilon}(qw + \eta < \tau).$$

By the Envelope Theorem,

$$\frac{\partial U_A(\pi_A|\tilde{w}_\epsilon)}{\partial \epsilon}\Big|_{\epsilon=0} = \lambda(k-\tau_0)\left[-\frac{1}{\Delta}\text{prob}(qw_0+\eta<\tau_0) + \frac{1}{\Delta}\text{prob}(q[w_0+\Delta]+\eta<\tau_0) + qf_\eta(\tau_0 - qw_0)\right].$$

Bribe τ_0, which solves $\max_\tau (k-\tau)\text{prob}(qw_0+\eta<\tau)$, must be interior and therefore satisfies the first order condition

$$(k-\tau_0)f_\eta(\tau_0 - qw_0) - \text{prob}(qw_0+\eta<\tau_0) = 0 \Rightarrow f_\eta(\tau_0 - qw_0) = \frac{\text{prob}(qw_0+\eta<\tau_0)}{k-\tau_0}.$$

Setting $\Delta \equiv \tau_0/q - w_0$, we obtain that

$$\frac{\partial U_A(\pi_A|\tilde{w}_\epsilon)}{\partial \epsilon}_{\big|\epsilon=0} = q(k-\tau_0)\text{prob}(qw_0+\eta<\tau_0)\left[-\frac{1}{\tau_0-qw_0}+\frac{1}{k-\tau_0}\right]<0$$

where we used the fact that $\tau_0 \leq \frac{1}{2}k \Rightarrow k-\tau_0 > \tau_0 - qw_0$.

Hence for ϵ small enough, using random wage distribution $\tilde{w}_\epsilon$ reduces crime compared to deterministic wage w_0. ■

Proof of Lemma 2. The proof is by example. We proceed case by case and assume throughout that $\lambda = 1$. Denote by $\overline{w}$ and $\underline{w}$ the maximum and minimum values in the support of F_w^1. Note that $w_0 \in (\underline{w}, \overline{w})$.

We first show that $\overline{R}_0 < \overline{R}_1$ can be consistent with $\overline{C}_0 < \overline{C}_1$. Consider the case where $k = qw_0$, F_{π_A} is a mass point at $k-\epsilon$ with $\epsilon > 0$, and F_η a mass point at 0. For any $\epsilon > 0$, $\overline{R}_0 = \overline{C}_0 = 0$. For $\epsilon > 0$ small enough $F_w^1(w_0-\epsilon) > 0$, which implies that for ϵ small enough,

$$\max_\tau (k-\tau)\text{prob}_{F_w^1}(qw<\tau) > k - \pi_A = \epsilon.$$

Hence for $\epsilon > 0$ small enough, $\overline{C}_1 = 1$. Furthermore, for $\epsilon > 0$ small enough, $F_w^1(w_0+\epsilon) < 1$, which implies that $\overline{R}_1 > 0$ since the agent never offers a bribe $\tau \geq k = qw_0$.

Let us show that $\overline{R}_0 < \overline{R}_1$ can be consistent with $\overline{C}_0 > \overline{C}_1$. Set F_{π_A} with full support over $[0,k]$, and

$$\eta = \begin{cases} \overline{\eta} & \text{with proba} \quad p \\ 0 & \text{with proba} \quad 1-p \end{cases}$$

with both $\overline{\eta} \leq \epsilon$ and $p \leq \epsilon$. For k large enough and $\epsilon > 0$ small enough, it is immediate that

$$\max_\tau (k-\tau)\text{prob}_{F_w^1}(qw+\eta<\tau) < \max_\tau (k-\tau)\text{prob}(qw_0+\eta<\tau)$$

since as k grows large, it is optimal for the agent to offer bribes respectively converging to $\overline{w}$ and w_0, and $\overline{w} > w_0$. This implies that $\overline{C}_0 > \overline{C}_1$. Let us now show that we can set $\overline{\eta}$ and p so that $\overline{R}_0 < \overline{R}_1$. A necessary and sufficient condition to obtain $\overline{R}_0 = 0$ is

$$k - qw_0 - \overline{\eta} > (k-qw_0)(1-p) \iff k - qw_0 > \frac{\overline{\eta}}{p}. \tag{5}$$

This condition expresses that it is optimal for the agent to offer a bribe $\tau = qw_0 + \overline{\eta}$ rather than $\tau = qw_0$ under the deterministic wage w_0. Similarly, under F_w^1, a sufficient condition to ensure that $\overline{R}_1 > 0$ is that the agent prefer offering a bribe $\tau = q\overline{w}$ over bribe $\tau = q\overline{w} + \overline{\eta}$. A sufficient condition for this is that

$$k - q\overline{w} - \overline{\eta} < (k - q\overline{w})(1-p) \iff k - q\overline{w} < \frac{\overline{\eta}}{p}. \tag{6}$$

Since $\overline{w} > w_0$, it is immediate that for any ϵ, one can find values $p, \overline{\eta} < \epsilon$, such that conditions (5) and (6) hold simultaneously. For such values, $\overline{R}_1 > \overline{R}_0 = 0$, which yields the desired result.

We now show that $\overline{R}_0 > \overline{R}_1$ can be consistent with $\overline{C}_0 > \overline{C}_1$. Set

$$\eta = \begin{cases} \overline{\eta} & \text{with proba} \quad p \\ 0 & \text{with proba} \quad 1-p \end{cases}$$

with both $\overline{\eta} \leq \epsilon$ and $p \leq \epsilon$. For k large enough and $\epsilon > 0$ small enough, we have that

$$\max_{\tau}(k-\tau)\text{prob}_{F^1_w}(qw + \eta < \tau) < \max_{\tau}(k-\tau)\text{prob}(qw_0 + \eta < \tau).$$

Set F_{π_A} as a point mass at a value π_A such that

$$\pi_A - k + \max_{\tau}(k-\tau)\text{prob}_{F^1_w}(qw + \eta < \tau) < 0 < \pi_A - k + \max_{\tau}(k-\tau)\text{prob}(qw_0 + \eta < \tau)$$

for all ϵ small enough. This implies that $\overline{C}_0 = 1 > \overline{C}_1 = 0$. In turn we obtain that $\overline{R}_1 = 0$. Finally, by choosing p and $\overline{\eta}$ such that (5) does not hold, one can ensure that $\overline{R}_0 > 0$.

Finally, we show that $\overline{R}_0 > \overline{R}_1$ can be consistent with $\overline{C}_0 < \overline{C}_1$. Set $\eta = 0$, $k = qw_0 - \frac{1}{2}\epsilon$ and

$$\pi_A = \begin{cases} k + \epsilon & \text{with proba} \quad p \\ k & \text{with proba} \quad 1-p. \end{cases}$$

It is immediate that $\overline{C}_0 = p$ and $\overline{R}_0 = p$. Furthermore, since $\max_{\tau}(k-\tau)\text{prob}_{F^1_w}(qw+\eta < \tau)$ is strictly positive and bounded away from 0 for ϵ small enough, it follows that for ϵ small enough $\overline{C}_1 = 1$ and $\overline{R}_1 < 1$. For p large enough, $\overline{R}_0 > \overline{R}_1$. This concludes the proof. ■

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