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CORRUPTIBLE LAW ENFORCERS: HOW SHOULD THEY BE COMPENSATED?*

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We study the optimal compensation policy for a corruptible inspector, charged with monitoring pollution from a factory. Our utilitarian approach focuses on the trade-off among corruption, pollution, and enforcement effort. Owing to the strategic interaction between factory and inspector, changes in compensation policy have surprising effects, e.g., raising the penalty for corruption may cause pollution to increase. We find that bribery is an inefficient way of encouraging the inspector to monitor; society should wipe out corruption.

> 'Only after leaving New York did I learn that a municipal sanitation inspector's job was not to collect money from door to door,' Anonymous economics professor.

Whenever a principal delegates enforcement authority, opportunities for corruption arise.[1] Sanitation inspectors, auditors, production foremen, and financial regulators all have discretion to 'sell out'. In developing countries especially, corruption severely impedes collection of taxes, enforcement of regulations, and management of public-sector enterprises.[2] Most scholarship assumes that corruption is bad and focuses on alternative ways to attack it.[3] Becker and Stigler (1974, p. 6), for instance, echo Adam Smith:

> The fundamental answer is to raise the salaries of enforcers above what they could get elsewhere,...A difference in salaries imposes a cost of dismissal...This cost can more than offset the gain from malfeasance.[4]

Using a simple model of delegated enforcement, we show that the relation between compensation policy and corruption may be much more complex. In our model, a regulator engages an inspector to monitor pollution from some factory. The regulator can neither directly control the inspector's monitoring effort, nor prevent the factory from bribing her. Word, however, of a bribe may leak out, in which case, the regulator can penalise both inspector and factory. The regulator can also motivate the inspector by paying her a commission on

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[1] See generally, Rose-Ackerman (1978) and Milgrom and Roberts (1988).

[2] In Taiwan, 80% of Certified Public Accountants (CPAs) interviewed by Chu (1987) admitted to having bribed public tax officials. In India, the Policy Group (1985) estimated that 76% of government tax auditors took bribes, and 68% of taxpayers filing through CPAs had given bribes. Alatas (1968) and Myrdal (1968) analyse the effects of corruption on economic development.

[3] Rose-Ackerman (1978) and Tirole (1990) are important exceptions.

[4] Such 'efficiency wages' have also been proposed as a way to deter shirking in general (Lazear, 1981).

fines (for pollution) collected from the factory. We find that, conditional on the inspector uncovering pollution, an increase in the penalty on the inspector for corruption may raise the bribe rather than reduce corruption. It takes a sufficiently large, discrete, increase in the penalty to eradicate bribery.

In fact, it is easy to wipe out corruption – the regulator need only abandon enforcement. For instance, when Hong Kong legalised off-track betting, police corruption fell substantially (Klitgaard, 1988, p. 116, n. 18). So the real issue is the trade-off among corruption, the primary harm at which the regulation is aimed, and enforcement effort. From a utilitarian standpoint, this trade-off is not *a priori* obvious. The prospect of a bribe encourages the inspector to monitor and the bribe itself represents a price for pollution, albeit one that does not go to the Government. On the other hand, bribery dilutes the penalty for pollution.

Moreover, changes in the inspector's compensation policy will also affect the strategic interaction between factory and inspector, and hence the pollution rate.[5] If, initially, bribery is profitable, raising the penalty on the inspector for corruption will reduce her incentive to monitor. The reduction in monitoring may reduce the expected penalty for pollution, hence the result may be more pollution.

In general, however, we find that, although bribes do encourage the inspector to monitor, they are an inefficient way of doing so. Given any degree of monitoring effort by the inspector, the pollution rate will be lower when compensation policies are adjusted to eradicate bribery. If the new pollution rate also exceeds first-best, welfare has unambiguously improved. If not, society can adjust the inspector's commission to ensure that the new pollution rate is exactly first-best. Since this is achieved with less monitoring, welfare must be higher. Accordingly, corruption should be wiped out.

We emphasise that this result does not depend on graft *per se* having any social cost. It does depend upon the regulator knowing whether the inspector failed to report pollution because of a bribe or for legitimate reasons. If the regulator cannot distinguish legitimate from illegitimate under-reporting, then he effectively has only one policy instrument – a penalty on the inspector for under-reporting, which is the mirror image of the commission on fines collected from the factory. With only a single instrument to influence two variables (the inspector's monitoring effort and the factory's pollution), the regulator may then find it optimal to tolerate some corruption.

I. RELATED RESEARCH

Most legal systems provide for a division of responsibility among legislature, executive, and judiciary. The legislature decides which acts should be prohibited, sets corresponding penalties, and lays out the framework of

[5] This strategic interaction also explains why, although the inspector is risk neutral, increases in the commission and the penalty for corruption have different effects. The inspector's incentive to monitor rises with the commission but falls with the penalty for corruption.

enforcement. For instance, Hong Kong water pollution laws specify maximum fines of HK$100,000 for the first offence, HK$200,000 for subsequent offences, and HK$5,000 for each day the offence is continued.[6]

Responsibility for enforcement falls to the executive. In Hong Kong, the Environmental Protection Department has charge of enforcement against water pollution. Typically, the enforcement agency has relatively little discretion over the laws and penalties that it is charged with enforcing. It will have more power over the compensation policy for its personnel. Even this power, however, is subject to the constraints of civil service regulations and appeal to the courts.

The judiciary completes the system. Courts apply the law to cases brought by the enforcement agency and impose sentences – within parameters set by the legislature. Judicial sentencing philosophy also guides penalties set by the enforcement agency in administrative proceedings. The reason is that aggrieved parties can always appeal the actions of an agency to the courts.

Taking this to be the context of our study, we assume that the structure of penalties for the primary harm of pollution is exogenous, while the enforcement agency has some discretion over the compensation policy for its inspectors. We limit the agency to linear incentives. These accord with the common practice in criminal sentencing of letting 'the punishment fit the crime'.[7] Linear schemes prevail in private contracts as well (Hart and Holmstrom, 1987).[8] Another perspective of our research is that it aims to analyse piecemeal policy reform.[9] This objective is not only realistic, but, as we emphasise below, the major conclusions apply *a fortiori* when the policy maker has the freedom to vary both incentives for enforcers and penalties for the primary harm.

By contrast, much recent research on collusion in organisations (Tirole, 1986, 1990; Felli, 1990; Kofman and Lawarree, 1993) assumes that policy-makers are free to seek the globally optimal solution. Our setting differs from this work in another important way – we let the inspector be subject to moral hazard in both monitoring effort and reporting. So corruption can potentially benefit society by rewarding the inspector for effort in monitoring. We show that it is optimal to eliminate corruption only when the regulator's information is good enough that he can distinguish legitimate from illegitimate under-reporting by the inspector.[10]

[6] Water Pollution Control Ordinance (1980), as amended, Chapter 358, Laws of Hong Kong. At current exchange rates, HK$1 is equivalent to 9 UK pence or 13 US cents.

[7] The Hong Kong judiciary has even published an explicit schedule for some offences. For instance, the penalties for trafficking in dangerous drugs are presently: grammes of drug (years of imprisonment): up to 10 g (2–5 yr), 10–50 g (5–8 yr), 50–200 g (8–12 yr), 200–400 g (12–15 yr), 400–600 g (15–20 yr), over 600 g (20+ yr). (R. *v.* Lau Tak-ming and Yeung Wai-shing and Others, Hong Kong Law Reports, Vol. 2, 1990, 370–87). Custodial sentences cannot exceed life, so cannot be strictly linear.

[8] There is considerable theoretical justification for linear incentive schemes. The arguments of Holmstrom and Milgrom (1987) directly fit our setting. Another explanation is unobserved heterogeneity in the tasks assigned to various inspectors (Melumad and Reichelstein, 1989), which, for the sake of simplicity, we do not model here.

[9] In public finance, a similar distinction arises between tax policy reform (e.g. Dixit 1975; Feldstein, 1976; Guesnerie, 1977) and optimal taxation (e.g. Diamond and Mirrlees, 1971).

[10] This is not a trivial result: the regulator could design compensation and enforcement policies so as to wipe out graft without ever being able to detect bribery. Tirole (1990) discusses a number of other circumstances where it may be optimal to allow some corruption.

Focusing on moral hazard in monitoring effort, Landes and Posner (1975) and Polinsky (1980) argued that privatisation might generate excessive enforcement. If, however, each harm has a single identifiable victim, Friedman (1984) showed that the social optimum can be achieved with privatisation if the right to collect fines is vested in the victims.[11] This line of work, however, does not explicitly consider how potential criminals will respond to changes in the regulator's policy. By contrast, we analyse both direct effects on potential criminals and indirect effects through concomitant adjustments in enforcers' behaviour.

Our research is closer in spirit to that of Pashigian (1975) and Chander and Wilde (1992). Pashigian emphasised that penalties for bribery would affect the rate of the primary harm. He, however, assumed that the rate of enforcement against the primary harm was exogenous. Chander and Wilde focus on the strategic interaction between tax collectors and taxpayers. Their setting differs from ours in that taxpayers can be required to submit reports, on which the tax collector can condition her actions. A key distinction between our work and that of Pashigian and Chander and Wilde is that we not only describe the effects of changes in government policy but also consider the corresponding normative questions.

II. SETTING

By releasing an amount w of untreated waste into the public sewer, a factory can avoid legal disposal which would cost $c(w)$. This avoided cost is a private benefit. We assume that $c(0) = 0$, $c(w)$ is strictly increasing, strictly concave, and differentiable, and $c'(w) = 0$ at $w = \bar{w}$. The waste causes external harm, $h(w)$, where $h(0) = 0$, and $h(w)$ is strictly increasing, convex, and differentiable. Denote the level of pollution that maximises the net benefit, $c(w) - h(w)$, by w^*. This 'first-best' level would be socially optimal if enforcement were costless. Generally, $w^* \geqslant 0$, where $w^* > 0$ means that it is socially optimal to allow some pollution.

Under the law, pollution is subject to a fine fw, and the responsible enforcement agency employs an inspector to enforce this regulation.[12] To monitor the factory with intensity μ, however, the inspector must incur unobservable effort $e(\mu)$, where $e(\mu)$ is strictly increasing, strictly convex, and differentiable, and $e(0) = 0$. The intensity $\mu \in [0, 1]$ represents the probability that the inspector will learn the factory's true pollution level, w, and secure evidence for successful prosecution. With probability $1 - \mu$, the inspector will procure no evidence of pollution. We assume that the factory knows the evidence that the inspector finds.[13]

[11] By contrast, in our setting, the offender's activity causes widespread harm. Our results also apply to enforcement against victimless crimes such as prostitution and sale of dangerous drugs.

[12] The rate f is exogenous and finite. As explained above, we maintain that the enforcement agency does not have the power to set penalties on the primary harm. Our justifications for a finite rate f are similar to those for assuming that the inspector's compensation policy must be linear. Moreover, a finite rate f may be the only way to ensure that the factory bears a heavier price for increasing pollution (Shavell, 1991; Mookherjee and Png, 1992).

[13] We implicity assume that it is too costly to require every potential source to report its pollution. This assumption seems appropriate in the case of illegal discharges into the public sewer. The assumption also

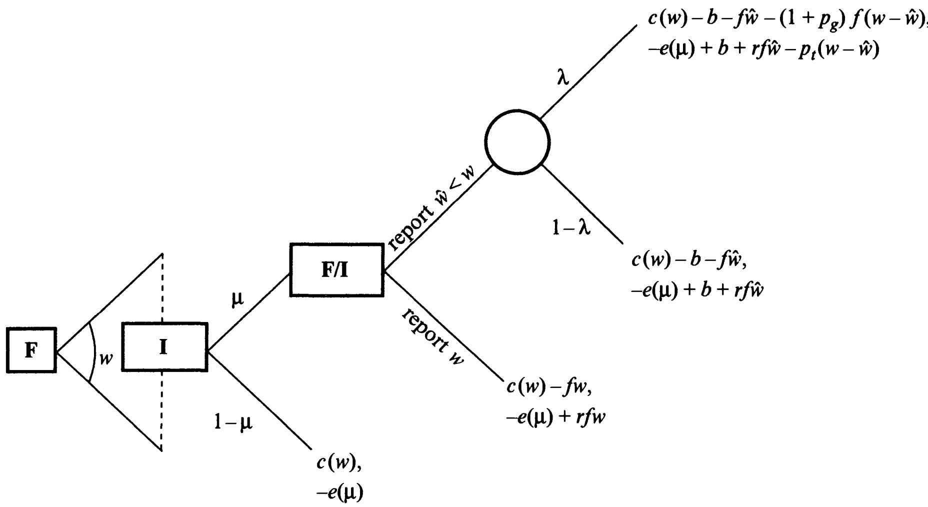

Fig. 1. Sequence of events. Note: first entry at end of tree is income of factory, second entry is income of inspector.

The inspector has discretion not only over her choice of effort, but also regarding the level of waste discharge, $\hat{w}$, that she reports to the regulator. To motivate the inspector, the regulator pays her a reward of r per dollar of fines for pollution collected from the factory. We assume that the penalties on the inspector for over-reporting are high enough and the costs to the factory of appealling an excessive report sufficiently low that the inspector will never over-report, so, $\hat{w} \leqslant w$.

The factory may bribe the inspector to report a level of pollution lower than that for which she has evidence. By doing so, the factory can reduce its fine from fw to $f\hat{w}$, while the inspector will receive a smaller reward, $rf\hat{w}$. In such cases, we assume that information about the bribe and the factory's true discharge, w, will leak to the regulator with an exogenous probability λ. The source of the leak may be an audit by another government agency, the press, or disgruntled employees of the factory. Leaks also reveal the bribe paid by the factory to the inspector.[14,15]

In the event of the corruption being discovered, the factory must pay not only the amount of fine evaded, $f(w-\hat{w})$, but an additional penalty for giving a bribe at a rate p_g, making a total of $(1+p_g)f(w-\hat{w})$. For its part, in the event

applies to many other harms, e.g. air pollution from motorcars and excessive household noise. Building on Graetz *et al.* (1986), Chander and Wilde (1992) analyse corruption in a context where the regulated entity (a taxpayer) can be required to file reports.

[14] Below, in Section VI, we explore the implications of assuming instead that the regulator receives information about pollution only and cannot tell whether the inspector under-reported for legitimate or illegitimate reasons.

[15] We do not consider the possibility that the regulator will employ a hierarchy of enforcers. When all officials are corruptible, Basu *et al.* (1992). Gangopadhyay *et al.* (1991), and Mishra (1992) show that it is useful to employ hierarchies in enforcement only when commission rates on fines collected are subject to some exogenous upper bound. If, as in our setting, there is no such bound, then any outcome achievable by a hierarchy can also be achieved by a single 'layer' of enforcers.

of a leak, the inspector must pay a penalty $p_t(w-\hat{w})$ for taking a bribe and under-reporting. Fig. 1 depicts the sequence of events.[16]

To summarise, the regulator's policy consists of three instruments – the rates of reward, r, penalty for taking bribes, p_t, and penalty for giving bribes, p_g.[17] Given a policy (r, p_t, p_g), the factory and the inspector simultaneously choose pollution, w, and monitoring intensity, μ, respectively. The two parties then jointly determine the bribe, if any. All parties are risk-neutral.

III. BRIBERY

To begin, suppose that the factory has polluted at level w, and the inspector has found evidence of the pollution. This sets the stage for us to identify the conditions under which corruption will emerge and the amount, b, of the bribe.

If the factory does not bribe the inspector, it must pay a fine of fw for pollution. If it does pay a bribe b and induces the inspector to report some $\hat{w} \leqslant w$, it will pay a smaller fine $f\hat{w}$ to the government.[18] With probability λ, however, word will leak out and the factory must pay an additional $(1+p_g)f(w-\hat{w})$ to the regulator. Thus, the factory expects to gain $[1-\lambda(1+p_g)]f(w-\hat{w})-b$ from a bribe.

If the inspector eschews corruption, she will receive a reward rfw from the regulator. If, however, she takes a bribe b and under-reports pollution, her reward will be smaller, i.e. $rf\hat{w}$, and the probability λ, she will be fined $p_t(w-\hat{w})$. Hence, her expected gain from under-reporting is $b-(rf+\lambda p_t)(w-\hat{w})$.

A bribe will change hands if and only if both factory and inspector can benefit. Therefore, a necessary and sufficient condition for bribery is that

$$[1-\lambda(1+p_g)]f > rf+\lambda p_t. \tag{1}$$

Both factory and inspector are corruptible, but whether bribery actually occurs depends endogenously on the regulator's policy. When bribery is profitable in the sense that the policy meets (1), we assume that the factory and the inspector choose a report $\hat{w}$ to maximise their joint profits, $[1-\lambda(1+p_g)]f(w-\hat{w})-(rf+\lambda p_t)(w-\hat{w}) = [f-\lambda f(1+p_g)-rf-\lambda p_t](w-\hat{w})$. By (1), joint profits are decreasing in $\hat{w}$, and so, will be maximised with

$$\hat{w} = 0. \tag{2}$$

[16] The scenario differs from the usual extensive form of a non-cooperative game in one respect: we assume that the amount of a bribe, if any, is determined by the Nash bargaining solution. Hence, the factory (F) and the inspector (I) act collectively at the node representing the choice of a bribe.

[17] We have also studied a related model in which rewards and penalties need not be linear but the factory is capable of only one level of pollution. In this context, expected payoffs are linear, hence the best responses of both inspector and factory have a 'bang-bang' quality. There is a unique mixed-strategy equilibrium. Compared to the model presented in this paper, the comparative statics are similar but the welfare implications differ slightly. The optimal policy is either to legalise the primary harm or to privatise enforcement. In either case, the regulator eliminates corruption.

[18] There are several reasons to think that the illicit contract between inspector and factory can be enforced. First, there may be a continuing relationship between the inspector and the factory, so that long-term costs of reneging outweigh the one-shot gain. Even if inspectors are rotated among factories, both parties must consider their reputations. For instance, owing to the spread of information among inspectors, if a factory reneges once, it may preclude itself from enjoying the benefits of corruption with all other inspectors. Likewise, informational networks among factories will deter inspectors from breaking agreements. Finally, either inspector or factory may resort to physical or other harassment.

The essential reason is that the two parties' gain from corruption increases with the degree of under-reporting faster than the expected cost in terms of additional penalties.[19]

Therefore, whenever the inspector finds evidence of pollution, w, and eschews bribery, she reports the true level. If, however, she conspires with the factory, she reports zero pollution. For simplicity, we postulate that, in this case, the factory and the inspector agree upon a bribe that balances their respective net gains,[20] i.e. $[1-\lambda(1+p_g)]f(w-\hat{w})-b = b-(rf+\lambda p_t)(w-\hat{w})$. By (2), this implies that

$$b = \tfrac{1}{2}\{[1-\lambda(1+p_g)+r]f+\lambda p_t\}\,w. \tag{3}$$

What is the impact of varying the inspector's compensation policy? Condition (3) shows that, if bribery is going on, small increases in the inspector's reward, r, or penalty for taking bribes, p_t, will merely raise the level of the bribe. Intuitively, the cost borne by the inspector for not reporting the pollution rises, so the inspector demands and receives a bigger bribe. In such cases, therefore, corruption rises.

Only if the reward or the penalty are increased sufficiently to overturn (1) will corruption fall. Then the inspector's demand rises beyond the factory's willingness to pay and corruption disappears. If society is unwilling to go so far, one way to reduce the bribe is to raise the penalty, p_g, on the bribe-giver (factory), while reducing the penalty, p_t, on the bribe-taker (inspector). This contrasts with the typical practice of punishing bribe-givers less severely than bribe-takers.[21,22]

IV. POLLUTION AND MONITORING

We see from (3) that the bribe increases with the pollution rate, hence the more the factory pollutes, the higher the 'price' it must pay. To understand the impact of government policy on the primary harm of pollution fully, we turn to consider the effect on *ex-ante* incentives – of the factory (to pollute), and the inspector (to monitor). Moreover, a full analysis of the 'extent' of corruption must consider effects on the likelihood of the inspector discovering pollution, as well as the effects considered in the previous section.

As described in Fig. 1, we suppose that the two parties move simultaneously, i.e. that neither the inspector nor the firm can precommit to their respective decisions. To start with, consider the case where bribery is profitable in the

[19] This result is due partly to our assumption that the rate of leaks, λ, is constant. The same result will hold if λ rises with the degree of under-reporting, but not too fast.

[20] Formally, this is the Nash bargaining solution where each party has equal bargaining power. Our results would not change substantially if the parties have unequal bargaining power.

[21] We are grateful to Omkar Goswami for this observation.

[22] We do not allow the regulator to use its knowledge of the setting and the strategic interaction between inspector and factory to make 'rational' inferences about the true rate of pollution. There are two reasons for this restriction. First, there is likely to be considerable heterogeneity among both inspectors and factories. The regulator may not have sufficient information about specific inspectors and factories to draw precise inferences about the true pollution rate from the inspector's report. Second, an inspector may be responsible for monitoring a number of factories at random. The regulator then will not know whether a factory was not cited because it was not inspected or because of corruption.

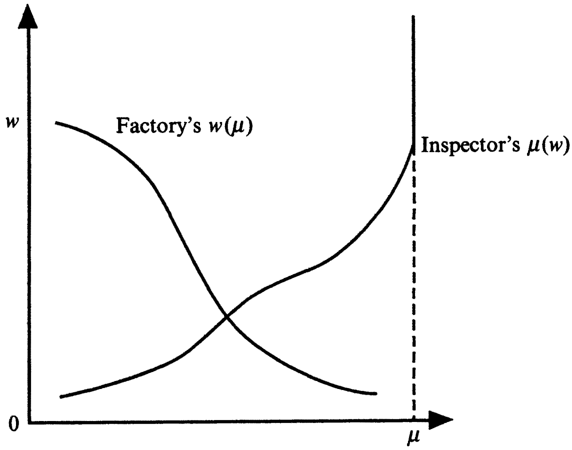

Fig. 2. Equilibrium behaviour.

sense that the regulator's policy meets (1). Recall that the inspector monitors at rate μ and, whenever she discovers evidence w, takes a bribe b and reports zero pollution. So the factory's expected profit from pollution w, is

$$\Pi^F(w;\mu) = c(w) - \tfrac{1}{2}\mu\{[1-\lambda(1+p_g)+r]f+\lambda p_t\}w - \mu\lambda(1+p_g)fw. \tag{4}$$

Since this function is concave, the factory will choose w such that

$$c'(w) = \tfrac{1}{2}\mu\{[1+\lambda(1+p_g)+r]f+\lambda p_t\}, \tag{5}$$

provided that $c'(0) > \{[1+\lambda(1+p_g)+r]f+\lambda p_t\}/2$. The factory's reaction function, $w(\mu)$, given by (5) is continuous. Further, since $c'(w)$ falls with w, the reaction function is monotone decreasing. Since $c'(w) = 0$ at $w = \bar{w}$, the pollution rate when the inspector does not monitor at all, $w(0) = \bar{w}$.

Next consider the inspector's incentives. Given that she expects pollution w from the factory, her expected income from monitoring at rate μ is

$$\Pi^I(\mu;w) = \mu(\tfrac{1}{2}\{[1-\lambda(1+p_g)+r]f+\lambda p_t\}w - \lambda p_t w) - e(\mu). \tag{6}$$

Thus, the inspector's reaction function $\mu(w)$ solves the equation

$$e'(\mu) = \tfrac{1}{2}w\{[1-\lambda(1+p_g)+r]f-\lambda p_t\}, \tag{7}$$

provided that $w > 0$.[23] The inspector's section function is continuous and monotone increasing in w. Further, $\mu(0) = 0$ and $\mu(\infty) = 1$.

Since the factory's reaction function is continuous and monotone decreasing in μ, we conclude that there always exists an equilibrium that is unique and involves both some pollution, $w > 0$, and some monitoring, $\mu > 0$ (Fig. 2). In the following analysis, we focus on the case of $\mu < 1$, while noting that essentially similar results apply when $\mu = 1$.[24]

[23] Since $e(\mu)$ is strictly convex and $e'(0) = 0$, it follows that the inspector chooses $\mu = 0$ whenever $w = 0$, and $\mu > 0$ otherwise.

[24] In the case of $\mu = 1$, some of the results hold in weak rather than strong form.

We can now study the effects of the regulator's policy on the behaviour of the factory and the inspector. First, consider the effect of a local increase in the penalty rate, p_t, for taking a bribe. By (3), the increased penalty will lead the inspector to demand and obtain a larger bribe. This, however, does not completely compensate the inspector for the increase in the expected penalty: while the factory and the inspector share the gains from under-reporting, the inspector bears the entire penalty if the conspiracy is discovered. Thus, the inspector's incentive to monitor falls. Graphically, the inspector's reaction function shifts to the left (see (7)).

From the factory's perspective, the increase in the bribe raises the price of pollution. So the higher penalty p_t will induce the factory to pollute less. Graphically, the factory's reaction function will shift downwards (see (5)). In equilibrium, the reduction in the inspector's incentive to monitor, however, has a countervailing effect on the factory: it cuts the expected price of pollution. To conclude, if the penalty, p_t, is higher, the monitoring intensity, μ, definitely will be lower, while pollution, w, may either rise or fall (Fig. 2).

Consider next a small increase in the reward rate, r. By (3), this will raise the bribe and hence the price of pollution. So, the factory will reduce pollution (its reaction function will shift downward). The higher bribe will increase the inspector's incentive to monitor (her reaction function will move to the right), further deterring the factory. The reduction in pollution, however, will discourage the inspector from monitoring. In equilibrium, the net effect is clearly to reduce pollution, while the monitoring intensity, μ, may rise or fall. By contrast, when the regulator raises the penalty for bribery, monitoring falls but the effect on pollution is ambiguous. So, although the inspector is risk-neutral, the carrot (reward for reporting pollution) and the stick (penalty for taking a bribe) have disparate effects.

Finally, consider a small increase in the penalty rate, p_g, on the factory for giving bribes. This will reduce the bribe (see (3)). The change in p_g affects the inspector only through the bribe; it clearly reduces her incentive to monitor (her reaction function shifts to the left). For the factory, the higher penalty outweighs the lower bribe, so it tends to pollute less (its reaction function shifts down). Since, however, the inspector monitors less, on balance, pollution may either rise or fall. Pollution will rise if the inspector's marginal disutility for effort does not increase too fast.

PROPOSITION 1. *When bribery is profitable, small changes in the regulator's policy have the following effects*:

Small increase in	Effect on Monitoring (μ)	Effect on Pollution (w)
Penalty on inspector for taking bribe, p_t	*Lower*	*Ambiguous*
Reward to inspector, r	*Ambiguous*	*Lower*
Penalty on factory for giving bribe, p_g	*Lower*	*Ambiguous*

Since bribery is profitable, it occurs whenever the inspector finds evidence of pollution. Thus the *ex-ante* corruption rate is simply the monitoring intensity,

μ, and the expected amount of bribery is μb. Many scholars have argued that raising officials' pay will reduce corruption (see, for instance, Myrdal, 1968, vol. II, pp. 955–7, and Becker and Stigler, 1974). In our context, higher wages 'work' by enabling the government to penalise the inspector more heavily for corruption. By Proposition 1, if the penalty rate, p_t, is higher, the corruption rate will drop. But, by (3), the bribe, when it occurs, will be larger, so the expected bribe may rise.

More significantly, raising p_t may so reduce the inspector's incentive to monitor that the factory will increase pollution. In general, Proposition 1 suggests that adjusting either rewards or penalties to reduce the corruption rate may mean adding to the primary harm of pollution. This highlights the potentially positive role of bribes: by giving inspectors stronger incentives to monitor, it serves to strengthen deterrence of the primary harm.[25] On the other hand, it is also possible for a change in policy to reduce both corruption and pollution. Accordingly, there is no universal trade-off between corruption and the primary harm.

Before we can characterise the optimal compensation policy, we must also analyse the behaviour of the factory and the inspector when bribery is not profitable. Accordingly, assume now that the regulator's policy does not satisfy (1). Then, although both inspector and factory are corruptible, bribery does not occur.

In this case, the inspector again monitors with intensity μ, but, whenever she discovers evidence of pollution, w, she reports it truthfully. So, the factory's expected profit, $\Pi^F(w;\mu) = c(w)-\mu f w$, hence its reaction function $w(\mu)$ solves

$$c'(w) = \mu f. \tag{8}$$

The inspector's expected income, $\Pi^I(\mu;w) = \mu r f w - e(\mu)$, hence her reaction function, $\mu(w)$, is given by

$$e'(\mu) = rfw. \tag{9}$$

The reaction functions, and hence the equilibria, are similar to those when bribery is profitable. As for the effects of the regulator's policy, the penalties for corruption obviously have no effect, since bribery does not occur. An increase in the reward rate increases the inspector's incentive to monitor, but leaves the factory's reaction function unaffected. So it unequivocally increases monitoring and reduces pollution.

V. WELFARE

We can now address the welfare trade-off among corruption, the primary harm of pollution, and enforcement costs. We find that it is optimal to eradicate corruption. In order to bias the analysis against this conclusion, we adopt a utilitarian approach: social welfare is simply,

$$S = c(w) - h(w) - e(\mu). \tag{10}$$

[25] Notice that, as long as bribery remains profitable, reported pollution is zero and does not respond to government policy – even while actual pollution may be falling. New York Police Commissioner Patrick Murphy gauged police corruption by the extent of activities such as prostitution and gambling (Klitgaard 1988, p. 117, n. 21). But how did Commissioner Murphy measure prostitution, etc.? Policy-makers who rely on information from subordinates risk being seriously misled.

This ignores all transfers, and, in particular, attaches no social cost to bribery *per se*.

Assume that the regulator does not face any budgetary limitations, so that any reward, r, and penalty for corruption, p_t, are feasible. Then, we have:[26]

PROPOSITION 2. *For every outcome when bribery is profitable, there exists another, in which bribery is not profitable, that yields higher welfare.*

We briefly outline the underlying argument. Consider any policy, (r, p_t, p_g), that meets (1), so that bribery is profitable. We construct an alternative policy (r', p_t', p_g) in the following way. First, set the penalty rate p_t' large enough that $p_t' \lambda > [1 - \lambda(1 + p_g)]f$, so, by (1), bribery is not profitable. Second, choose the reward rate

$$r' = \frac{1}{2}\left[1 - \lambda(1 + p_g) + r - \frac{\lambda p_t}{f}\right].$$

By (7) and (9), the inspector's incentive to monitor is left unaffected. Regarding the factory's incentive to pollute, the right-hand side of (8) less that of (5) is $\frac{1}{2}\{[1 - \lambda(1 + p_g) - r]f - \lambda p_t\}\mu$, which is positive since, by assumption, bribery is profitable under the original policy. Thus, the alternative policy reduces the factory's incentive to pollute – essentially because it must then pay the full fine for pollution rather than a smaller bribe. The result is that both pollution and monitoring will be lower. If pollution exceeds the first-best rate under both original and new policies, welfare has unambiguously improved. If not, society should reduce the reward below r' to ensure that the new pollution rate is exactly first-best. Then the new policy will induce first-best pollution with less monitoring, hence must be better.

Thus bribery is an inefficient way to motivate the inspector. The key to this result is the disparate effects of carrot and stick on the strategic interaction between inspector and factory. Given any compensation policy that generates bribery, the regulator can exploit these differences to construct another policy that yields less pollution without raising monitoring effort. Under this alternative, corruption is eradicated.[27]

Two other aspects of the optimal compensation policy are worth noting. First, the optimal pollution rate exceeds the first-best. If it did not, the regulator could raise welfare by slightly reducing the reward, r. This would raise pollution (towards first-best), while reducing monitoring effort.

Second, to motivate the inspector, Becker and Stigler (1974) advocated privatising law enforcement. In our context, this could mean a reward rate of 100%. Privatisation induces the inspector to maximise $\mu f w - e(\mu)$, the difference between the expected revenue from collecting fines and her effort in monitoring. By contrast, social welfare is $c(w) - h(w) - e(\mu)$, the difference between the net benefit from pollution and the inspector's effort. Unless the fines for pollution can be set to align these two objectives, privatisation need not be optimal.

[26] See Mookherjee and Png (1992*b*) for a formal proof.

[27] In related work, Kahn and Silva (1992) assume that the law enforcer's bribe is the entire legally stipulated fine. In this case, it may be optimal to allow corruption.

Put differently, the optimal reward rate balances the marginal benefit of reducing pollution against the marginal cost of the inspector's effort in monitoring. There is no necessary reason why these should balance at a reward of 100%.[28] Privatisation may result in inadequate or excessive enforcement. By contrast, earlier work by Landes and Posner (1975) and Polinsky (1980) only showed that privatisation might cause over-enforcement.

VI. VARIATIONS AND EXTENSIONS

In the preceding analysis, we assumed that (i) the inspector's compensation policy was linear, (ii) the penalties for pollution were exogenous, and (iii) when a leak occurred, the regulator could distinguish legitimate from illicit under-reporting by the inspector. Proposition 2 shows that even when the regulator is limited by (i) and (ii), corruption is not an efficient way to motivate the inspector. Accordingly, this result applies *a fortiori* when the regulator has the freedom to set non-linear incentives and vary the penalties for pollution.[29]

Our results also apply when the penalty on the inspector for corruption is dismissal or, more generally, does not vary with the degree of under-reporting. The main difference in the arguments is a technical one: in this case, the factory's reaction function will be discontinuous at a single value of μ, hence pure-strategy equilibria may not exist. There will, however, always be a mixed-strategy equilibrium, based on which we can prove the equivalent of Propositions 1 and 2.

Regarding the information structure, suppose instead that leaks to the regulator do not distinguish between legitimate and illegitimate under-reporting. Then, in the event of a leak, the regulator still can penalise the inspector, at the rate p_t say – for failing to report pollution. So, the inspector will bear the penalty if she either obtains no evidence of pollution or deliberately withholds such evidence. The penalty essentially is a negative reward. With only a single instrument to influence two variables (the inspector's monitoring effort and the factory's pollution), the regulator may then find it optimal to tolerate some corruption.

To outline the argument, make the inessential assumption that the regulator fines the factory at the same rate f whether its pollution is reported by the inspector or by some third-party leak. Then bribery will be profitable if $(1-\lambda)f > rf+\lambda p_t$, and in this case the bribe will be $b = \frac{1}{2}[(1-\lambda+r)f+\lambda p_t]\,w$. Assuming that bribery is profitable, the factory's expected profit is $\Pi^F(w;\mu) = c(w)-\frac{1}{2}\mu[(1-\lambda+r)f+\lambda p_t]\,w-\lambda f w$, hence its reaction function is $c'(w) = \frac{1}{2}\mu[(1-\lambda+r)f+\lambda p_t]+\lambda f$. Further, the inspector's expected income, $\Pi^I(\mu;w) = \mu[\frac{1}{2}(1-\lambda+r)f+\lambda p_t)]\,w-\lambda p_t\,w-e(\mu)$, so that her reaction function solves $e'(\mu) = \frac{1}{2}w[(1-\lambda+r)f+\lambda p_t]$.

An increase in the penalty p_t would raise the expected price of pollution,

[28] The following example shows that the optimal reward rate need not be 1. Let $c(w) = \log w$, $e(\mu) = \mu^2/2$, $h(w) = 1/\delta w^\delta$, where $\delta \geqslant 1$. Then the first-best pollution, $w^* = 1$. When bribery is not profitable, (8) and (9) show that pollution will be $w' = 1/fr^{-1/2}$. So if $f > 1$ and $r = 1$, pollution, $w' < w^*$, which cannot be optimal. Thus, we must have $r < 1$.

[29] We are grateful to a referee for this observation.

hence lead the factory to pollute less. By contrast with Proposition 1, however, the increase in p_t, will raise the inspector's incentive to monitor – because this penalises low effort in monitoring more than it penalises corruption. An increase in the reward, r, also reduces the factory's incentive to pollute and raises the inspector's incentive to monitor. Since changes in the reward and the penalty have similar effects on the inspector, the regulator cannot be sure that eradicating corruption will not also increase monitoring.

If the inspector's marginal disutility for effort increases sufficiently fast, monitoring will on balance fall, hence eliminating graft is desirable since it reduces both pollution and monitoring. On the other hand, if her marginal disutility for effort is close to constant and society attaches relatively high weight to the cost of monitoring (relative to the net harm from pollution), then welfare may fall. In this case, wiping out corruption would be so costly relative to the benefit that the regulator would rather allow the factory to bribe the inspector and thereby avoid the full fine for pollution.[30]

VII. CONCLUDING REMARKS

> 'In Asia,... China and Vietnam, are also bedevilled by corruption and nepotism... Singapore has succeeded in being different[.].'[31]

Singapore's solution is no secret: 'the way to get the best in government... is to pay them nearly their market value.'[32] Hong Kong follows a similar policy. The puzzle then is why other governments do not follow suit.

To address this question, we considered a setting in which corruption benefits society by encouraging officials to invest effort in monitoring. To bias our analysis in favour of bribery, we adopted a utilitarian approach. We found that, if the government can distinguish between legitimate and illicit under-reporting by the inspector, bribes are an inefficient way of motivating effort. Only if the government cannot distinguish between legitimate and illicit under-reporting might it be optimal to allow corruption.

Furnivall (1956) was surprised to observe that, by contrast to colonial Burma, corruption was almost unknown in (Dutch) Java.[33] He attributed the absence of graft in Java partly to a tradition of 'complaints' among the people. '[O]ne chief duty of the Controleur, as he moved among the people, was to detect and bring to light oppression by encouraging them to complain' (Furnivall (1956), p. 270).[34] This was reinforced by giving the Regent, head of the native administration, security of tenure: 'In Java, the Regent is

[30] Similar results apply when the regulator receives no leaks at all, i.e. $\lambda = 0$. Then, the regulator clearly has only one policy tool, namely, the reward, r. If and only if $r < 100\%$, bribery will occur and an increase in r will reduce pollution, while monitoring may rise or fall. In addition, it may be desirable to allow some corruption.

[31] Lee Kuan Yew, Singapore Senior Minister, as reported in 'SM Lee: Pay to get the best to be ministers', *Straits Times* Weekly Edition, 22 January 1994, p. 13.

[32] Ibid.

[33] [T]hat corruption should be unknown in [Netherlands India] general administration, with a Government intervening so actively in every branch of social life, seems almost incredible' (Furnivall (1956), pp. 269–70).

[34] The Controleur was a European official who linked the European and native administrations of Netherlands India.

permanent. His position and high pay protect him against the temptation to accept petty bribes, and concern for his own authority and prestige makes him jealous of the influence of corrupt subordinates' (p. 271).

By contrast, Furnivall noted that, in Burma, 'Those who gained their ends by bribery naturally made no complaint, and complaints from those who suffered were suspect as malicious' (p. 170). In the absence of information enabling the government to distinguish official graft from honest mistakes, our analysis suggests that it may be socially optimal to allow corruption. Consistent with this prescription, Furnivall observed that

> the [Burmese] Government sometimes deplored the prevalence of corruption, sometimes minimized it, but did nothing to stop it (p. 170).

In addition to the normative issue of when bribes should be permitted and when they should be attacked, our analysis also lays the foundation for empirical scholarship on corruption. It shows, for instance, that the relation between penalties for corruption and the extent of bribery may reverse direction. Starting from a setting where bribery occurs, small increases in penalties may raise bribery, while larger increases will reduce it. Our analysis also shows that changes in rewards to law enforcers may have ambiguous effects on the number of offenders reported, total fines collected, and the extent of bribery. It suggests that the best measure of the efficacy of rewards is the incidence of the primary harm. So, for instance, in India, the value of paying rewards to customs officials should be assessed by their effect on the open market price of the product subject to import controls.

We wish to highlight one direction for future research. Our analysis implicitly assumed that all officials are equally prone to graft. Realistically, however, officials may vary in the degree to which they are corruptible. Besley and McLaren (1993) address the optimal policy towards heterogeneous officials in the context of tax compliance. They identify conditions under which it may be optimal for the revenue authority to allow corruption among tax collectors. We believe that a similar result may hold in the law enforcement setting. It may be optimal to allow bribes because policies sufficient to eradicate graft among corruptible officials will induce excessive enforcement effort by the honest.[35]

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