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Abstract

We model an enforcement problem where firms can take a known and lawful action or seek a profitable innovation that may enhance or reduce welfare. The legislator sets fines calibrated to the harmfulness of unlawful actions. The range of fines defines norm flexibility. Expected sanctions guide firms' choices among unlawful actions (marginal deterrence) and/or stunt their initiative altogether (average deterrence). With loyal enforcers, maximum norm flexibility is optimal, so as to exploit both marginal and average deterrence. With corrupt enforcers, instead, the legislator should prefer more rigid norms that prevent bribery and misreporting, at the cost of reducing marginal deterrence and stunting private initiative. The greater the potential corruption, the more rigid the optimal norms.

Keywords: norm design, initiative, enforcement, corruption.
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Contents

1 Introduction

It is generally recognized that when private actions generate externalities, for instance in the form of diffuse social harm, public intervention can improve welfare. In this case, public policy must trade off the benefit of social harm reduction with enforcement and compliance costs, and possibly with the agency costs due to bureaucrats' self-serving behavior.

It is less frequently acknowledged that norms and their enforcement may have yet another cost: that of stifling private sector innovation that may open profit opportunities but entail risks for society, such as research and development (R&D) activity. The idea that public intervention may stifle valuable private initiative dates back at least to the work of Friedrich Hayek (1935, 1940). But there is no formal analysis, to the best of our knowledge, of how the optimal design and enforcement of norms should take into account the benefits and risks stemming from private innovative activity.

In this paper we propose such an analysis, by modeling a setting where firms can take a known and lawful action ("business as usual") or exert *initiative* to learn about new profitable actions ("innovation"). Learning about new profitable actions opens the way to private activities that may benefit or harm society – creating a positive or negative externality. The legislator must decide how to take into account both the possible social benefits and the risks created by private initiative. In designing and enforcing norms, he can act on two different margins: the private decision to invest in research effort or not, and the choice of the private actions once innovation succeeds.

One class of examples arises in connection with R&D activity and scientific uncertainty. For instance, a biotech firm may either produce traditional seeds or research new genetically modified (GM) seeds that promise higher yields but pose unknown risks to public health (causing allergies in consumers or spreading to neighboring plots).

A second class of examples refers to the introduction of new products in an uncertain market environment. For instance, a software developer may either market its existing products or try to develop a new application tied to an operating system. Depending on the circumstances prevailing when the innovation will be marketed, the new software may raise consumer welfare (due to its greater ease of use) or induce market foreclosure. Which effect will prevail depends on the alternative products and firms that will be present on the market when the new software will be introduced. Hence, apart from the strategic intentions of the software company regarding the possible effects of its new application, the true consequences of the innovation on market equilibria will depend also on a set of random events that are out of the control of the developer.

Yet another class of cases may occur in financial markets: financial innovation, such as the introduction of new instruments or markets, may create new profit opportunities for intermediaries as well as new hedging opportunities for investors, but may also create new dangers for uninformed investors who cannot master the information necessary to handle novel instruments or trade on new markets.

In each of these cases, public policy should design fines and enforcement so as to prevent the actions most harmful to society, while trying to preserve firms' incentives to innovate.[1] The range of fines chosen by the legislator defines the extent to which fines can be calibrated to the social harmfulness of private actions. In other words, it determines *norm flexibility.*

The expected sanctions will then guide both how firms exploit innovation and their incentives to seek innovation in the first place. Otherwise stated, sanctions may induce firms to choose less socially harmful actions once they have innovated – the well-known *marginal deterrence* effect – and/or reduce the probability of innovation, and thereby discourage any new action by the firm irrespective of its harmfulness – an effect that we label *average deterrence*. While marginal deterrence is always desirable and calls for more enforcement, average deterrence improves welfare only when social harm is sufficiently likely. When instead social harm is unlikely, average deterrence calls for lower enforcement to avoid stifling innovation too much.

Indeed, if the social risks stemming from private innovation are sufficiently remote, it is optimal to adopt a "laissez-faire" regime (a per-se legality rule), where private initiative is effectively free to unfold its effects. Interestingly, if initiative is needed to learn about new actions a laissez-faire regime is more likely to be optimal than in the traditional model where firms are not required to make any effort to learn about such actions. In this sense, when innovation is an important component of private activities, norms should be less interventionist.

Another result of the paper is that the optimal degree of flexibility of the law depends on the loyalty of enforcers. If enforcers can be trusted to be completely loyal, the legislator should choose the maximum degree of norm flexibility, so as to maximize marginal deterrence. When instead enforcers can be corrupted, the optimal design and enforcement of norms must take their incentives into account. Enforcement officials can extract a bribe from firms in exchange for misreporting their actions, leading to lower fines for noncompliers. In this case the legislator cannot simply rely on stiff fines to repress the most harmful actions, lest firms will prefer to bribe officials rather than refrain from such actions. In order to cope with bribery, the legislator has to tolerate relatively more harmful actions, leaving some rents to firms. This decreases marginal deterrence compared to the case where

[1] For instance, in the example where product innovation may lead to entry foreclosure, competition policy should try to prevent abuses of dominant positions without chilling the incentives to innovate.

enforcers are loyal. To compensate this decrease in marginal deterrence, the legislator will have to rely more heavily on average deterrence by reducing the incentives to invest in initiative: when social harm is sufficiently likely, it is best to raise the minimum fine so as to discourage initiative.

Therefore, the more corruptible the enforcers, the more rigid the optimal norm: the range of fines decreases with the degree of enforcers' loyalty, which is measured by the minimum bribe that induces the enforcer to misreport (a higher minimum bribe corresponds to greater loyalty). Hence, agency problems in enforcement reduce the flexibility of norms, limiting marginal deterrence and affecting average deterrence.

This paper contributes to two research areas: that which focusses on the costs and benefits of public intervention in the presence of market failures, and that which deals with law enforcement. In the first of these two areas, several papers highlight that intervention should be curtailed if its enforcement is very expensive or generates the incentive to demand and pay bribes to enforcers (Krueger, 1974; Rose-Ackerman, 1978; Banerjee, 1997; Acemoglu and Verdier, 2000; Glaeser and Shleifer, 2003; Immordino and Pagano, 2005, among others). This literature does not consider the effect of norms on innovative activity by the private sector. Public intervention can affect innovation at both its typical stages: (i) learning of new products or processes, and (ii) their industrial and commercial exploitation. It can reduce the incentives to invest in learning, or direct newly acquired knowledge to the use that is least harmful to society; considering both of these aspects leads to novel results.

Our paper also contributes to the literature on optimal law enforcement (Becker 1968, Becker and Stigler 1974, Polinsky and Shavell 2000 and 2001, Shavell 1993, among others). The model put forward here has some elements in common with the "activity level" model analyzed in this literature.[2] In this model, private benefits and social harm depend on two different decisions of private agents – an activity level (say, how long an individual drives a car) and a level of precaution (driving speed) – and the analysis tipically compares the effects of different liability rules (strict versus fault-based liability). In our paper the role of initiative is reminiscent of the activity level, while the choice of new actions parallels the choice of precaution. But the information structure of our setting differs from that of these models, since the choice about initiative is made before the state of the world is known, while in the "activity level" model uncertainty plays no role. Uncertainty allows us to analyze how the optimal norm and its enforcement change depending on the likelihood that innovation will cause social harm.

The literature on law enforcement concentrates on the marginal deterrence effect of enforcement (Stigler, 1970; Shavell, 1992; Mookherjee and Png, 1994, among others). As

[2] See, for instance, Shavell (1980, 2006) and Polinsky and Shavell (2000).

already mentioned, in our setting enforcement may also reduce the probability of innovation and thereby discourage any action by the firm, whether socially harmful or beneficial. This effect, which we label average deterrence, arises because in our setting the set of possible private actions is not exogenously given, as traditionally assumed, but depends on a private decision (innovation), which can in turn be affected by public intervention.[3] The endogeneity of the set of actions by the agent is reminiscent of Aghion and Tirole (1997), and as in that paper the effort of the principal (enforcement by officials) depresses the initiative of the agent (innovation by firms). The difference is that in our model the principal's effort cannot directly substitute for the firm's initiative: the legislator can depress the biotech's investment in R&D or affect the type of seeds that it will market if successful, but cannot itself undertake R&D.

Our setting also allows us to address the issue of the optimal degree of flexibility of the law, measured by the range of fines applicable by enforcement officials. This is a mute issue in the traditional analysis of enforcement, where the legislator always wishes maximum flexibility so as to maximize marginal deterrence – as indeed we find under loyal enforcement. (This may explain why the range of fines is exogenous in the law enforcement literature.) However, the choice of flexibility becomes relevant when there are agency problems in enforcement, as also shown in this paper. This echoes other results in the literature showing that collusion reduces the instruments that principals can use to provide incentives to agents – a point first made by Tirole (1986) in his analysis of a three-tier contracting relation between a principal, a supervisor and an agent. Tirole shows that the optimal contract offers low-powered incentives to the agent to prevent him from colluding with the supervisor. Laffont and Tirole (1993, Chapter 11) make a similar point in the context of the regulation of industry.

Our paper is organized as follows. Section 2 presents the model. Section 3 analyzes the case of loyal officials, and Section 4 that of unloyal officials. Section 5 concludes.

2 The model

We consider a model with a profit-maximizing firm, a benevolent legislator and – for the time being – a loyal enforcer. The firm can either choose one among several known and

[3] To our knowledge, Kaplow (1995) is the only paper where the design of the law affects agents' learning decisions. In his setting, more complex rules allow better control over individual behaviour but are harder for people to understand ex ante and for courts to apply ex post. In his setting, individuals can choose not to learn, and take actions ignoring the associated effects (and fines). Our model differs from his in that new actions can be taken only upon learning. Moreover, our notion of norms' flexibility refers to the ability to fine-tune sanctions to actions, while Kaplow's notion of norms' complexity refers to the detail in the description of what is lawful or not.

lawful actions, or invest in learning how to carry out new actions, whose private and social effects are unknown *ex ante*. For instance, a biotech firm may either produce traditional seeds or experiment with a new GM seed that promises higher yields but poses unknown risks to public health.

The legislator may constrain the firm's operations by legal norms and associated penalties. To maximize social welfare, he must take into account the tradeoff between the social dividend arising from the firm's innovations (a larger harvest, in the previous example) and the potential social damage stemming from them (a public health hazard). The key issue that we wish to explore is how this tradeoff shapes the optimal design of legal norms and their enforcement.

The firm can choose the *status-quo* action a_0 (planting traditional seeds) with associated profits Π_0 and welfare W_0. Action a_0 is the most profitable of implementable legal actions. Alternatively, the firm can consider a set of new actions $A = [\underline{a}, \overline{a}]$, with associated profit $\Pi(a) \in \left[\underline{\Pi}, \overline{\Pi}\right]$ that is differentiable, increasing and concave in $a \in A$.

Depending on the state of nature s, the social consequences of new actions are described by one of two different functions. With probability $1 - \beta$, a good state $s = g$ occurs: new actions improve welfare, according to an increasing function $W = W(a)$ such that $W(\underline{a}) \geqslant W_0$ and $W(\overline{a}) = \overline{W}$. In this state, there is no conflict between private and social incentives, since $\Pi'(a) > 0$ and $W'(a) > 0$. With probability β, instead, a bad state $s = b$ occurs, where new actions have a negative social externality. Welfare is described by a decreasing function $W = w(a)$ such that $w(\underline{a}) \leqslant W_0$ and $w(\overline{a}) = \underline{W} < \overline{W}$ with $w''(a) \leqslant 0$. In this case, private incentives conflict with social welfare since $\Pi'(a) > 0$ but $w'(a) < 0$. Nature chooses which state of the world occurs; hence, the probability β of the bad state (social harm) is an *ex-ante* measure of the misalignment between public interest and firms' objectives.[4] In our example, β is the prior probability that the GM seeds will be hazardous to public health.

The firm knows from the beginning how to carry out the status-quo action a_0. In contrast, carrying out any new action, requires an investment in learning (experiments with GM seeds), which accordingly will be referred to as "initiative". If the investment is successful, the firm will discover how to carry out the new actions $A = [\underline{a}, \overline{a}]$. In this case, the firm also learns the state of nature, that is whether its innovation is socially harmful. Proceeding with our example, the biotech company learns not only how to produce new GM seeds, but also the dangers that they pose to public health.

[4] A more complex setting can be imagined, in which social harm arises only over a subset of the new actions in A, so that even in the bad state not all the projects are socially harmful. This extension would complicate the analysis without adding any substantive result.

The amount of resources I that the firm invests in learning determines its chances of success: for simplicity, the firm's probability $p(I)$ of learning how to carry out the new actions A is assumed to be linear in I, i.e. $p(I) = I$ with $I \in (0, 1]$. The cost of learning is increasing and convex in the firm's investment. For simplicity we assume

$$c(I) = c\frac{I^2}{2}$$

with $c > \overline{\Pi} - \Pi_0$ to ensure an internal solution.

The institutional framework in the design and enforcement of norms is as follows. The legislator writes the norm, which specifies legal and unlawful actions and the fines to be inflicted. The enforcement officials seek evidence on noncomplying firms and report it to the judges (or authority commissioners) who apply the norm. Since we are assuming that judges never make errors, their decisions are completely dependent on the evidence that the officials report. Moreover, in the benchmark model we assume that officials are loyal and report all the collected evidence. For this reason, in the benchmark model, norm design and enforcement are entirely chosen by the legislator, since neither officials nor judges have any real decision to take. However, in Section 4, the role of corrupt officials will be explicitly considered when we analyze the case in which they try to exploit their discretionary power.

The norm written by the legislator specifies how to distinguish between legal and illegal actions, and how the latter are punished. Thereby it determines the scope of enforcement activity. Norms can differ by their degree of flexibility, that is, by the extent to which penalties can be calibrated according to the consequences of the firms' actions. We consider a norm written as follows:

> The action $a \in A$ is illegal if ex-post socially damaging, i.e. if $W \leqslant W_0$. Illegal actions are sanctioned according to a fine schedule $F(w(a)) = F(a)$ chosen in the interval $\left[\underline{F}, \overline{F}\right]$ obeying a principle of proportionality, i.e. fines are non-decreasing in social harm $W_0 - w(a)$.

Therefore, norms have three features. First, they are effect-based, that is, they punish only actions that are *ex-post* socially damaging and in proportion to the social harm they cause.[5] Second, the legislator sets the boundaries of enforcement activity. These boundaries consist of a minimum fine $\underline{F} \in \left[F_{\min}, \overline{F}\right]$ and a maximum fine $\overline{F} \in [\underline{F}, F_{\max}]$ and a general principle of proportionality, where $F_{\min}$ and $F_{\max}$ are boundaries that characterize the legal system.[6] Third, the closer the minimum and the maximum fine, the lower the flexibility

[5] For a discussion on an effect-based interpretation of antitrust norms, see Gual *et al.* (2005).

[6] The common wisdom among lawyers is that $F_{\min} > 0$, meaning that illegal actions must be punished. But in principle the legislator may wish to abstain from punishing or subsidize certain illegal actions, as in the case of leniency programs for "whistleblowers" in antitrust enforcement (Motta and Polo, 2003).

that the legislator retains in setting the fines. Hence, the degree of flexibility is defined by the range of fines $\left[\underline{F}, \overline{F}\right]$ specified in the norm.

Since firms choose actions and initiative according to the level of the corresponding expected fines, the legislator has to set not only the level of fines but also their enforcement, that is, the amount of resources E devoted to detecting non-complying firms (for instance, the budget allocated to the environmental or health protection agency). These resources determine the probability $q(E)$ that the enforcer correctly identifies the action chosen by the firm and learns its social consequences W, and therefore its lawfulness. For simplicity, we assume the probability $q(E)$ to be linear in E, i.e. $q(E) = E$. The cost of the enforcement effort is convex, implying decreasing returns to enforcement: $g' > 0$ and $g'' > 0$ for $E \in (0, 1]$, with $g(0) = g'(0) = 0$ and $\lim_{E \to 1} g(E) = \lim_{E \to 1} g'(E) = \infty$. With probability $1 - q(E)$, the authority's investigation does not unearth enough evidence to inflict any fine on the firm.

The timing of the model is described in Figure 1. At time 1, the legislator writes the norm, which determines the minimum fine $\underline{F}$, the maximum fine $\overline{F}$, and the fine schedule $F(a) \in \left[\underline{F}, \overline{F}\right]$. It also allocates the resources E to enforcement. At time 2, the firm, knowing the norm and the enforcement level, chooses its initiative I and learns how to carry out the new actions with probability $p(I) = I$ and which is the state of the world. At time 3, the firm chooses an action, conditional on what it learnt in the previous stage. Finally, at time 4 actions produce their private payoffs Π and their social effects W; enforcement officials collect evidence with probability $q(E) = E$ and report it to judges, who determine the actual fines.

[Insert Figure 1]

Finally, we assume the following ranking among payoffs:

$$\overline{W} - W_0 > \overline{\Pi} - \Pi_0 > \overline{F}. \tag{1}$$

The first inequality implies that in the good state, social gains exceed private ones, or, equivalently, that new actions in good state increase consumer surplus as well as producer surplus. The last inequality says that the maximum payoff from initiative exceeds the maximum fine even when this is inflicted with certainty. According to this assumption, we focus our analysis on the case of incomplete deterrence, that is, firms always prefer to take some unlawful action if they learn how to take it.

3 Loyal officials

We now proceed to analyze the equilibrium of the game in the benchmark case where enforcement officials are loyal in reporting the collected evidence. We solve the game backwards, starting from the last stage, in which the firm chooses its action.

3.1 Firm actions

The choice of actions at stage 3 depends on whether the firm's initiative was successful or not, and on the fine schedule $F(a)$ designed by the legislator. If the initiative was unsuccessful, under our assumptions the firm prefers the *status-quo* action a_0 rather than a random new action. Let us consider the case in which the initiative was successful, so that it allows the firm to take new actions $a \in A$. If these are not socially harmful ($s = g$), all of them are lawful, so that the firm chooses the profit-maximising action $\overline{a}$, which also yields the maximum welfare $\overline{W}$. If instead the new actions produce a negative externality ($s = b$), and therefore are unlawful, under the incomplete deterrence assumption (1) the firm chooses the unlawful action that maximizes its profits, net of the expected fine.

Then, given the fine schedule $F(a)$, the firm will select the action

$$\widehat{a} = \arg\max_{a \in A}[\Pi(a) - EF(a)]$$

The features of the optimal fine schedule will be analyzed later on, when optimal policy design will be considered. We summarize the above discussion in the following Lemma:

Lemma 1 *At stage* 3*, given* E *and* $F(a)$*, the firm chooses the following actions:*

- a_0 *if learning is unsuccessful;*
- $\overline{a}$ *if learning is successful and new actions are not socially harmful* ($s = g$)*;*
- $\widehat{a}$ *if learning is successful and new actions are socially harmful* ($s = b$)*.*

3.2 Firm initiative

At stage 2 the firm chooses its initiative I so as to maximize its expected profits, given the optimal actions that it will choose at stage 3. In terms of our example, the biotech firm chooses how much to invest in R&D on GM seeds, taking into account which seeds it will produce and market if its R&D effort is successful. Its expected profits at this stage are:

$$\mathrm{E}(\Pi) = \Pi_0 + I\left\{\beta[\Pi(\widehat{a}) - EF(\widehat{a})] + (1-\beta)\Pi(\overline{a}) - \Pi_0\right\} - c\frac{I^2}{2}, \tag{2}$$

where the first term is the *status-quo* profit, the second term is the expected gain from initiative (net of the expected fines) and the third term is the cost of initiative.[7]

Lemma 2 *At stage 2, given E and $F(a)$, the optimal level of initiative is:*

$$\widehat{I} = (\beta[\Pi(\widehat{a}) - EF(\widehat{a})] + (1-\beta)\Pi(\overline{a}) - \Pi_0)/c.$$

Proof. The result follows immediately from the first order condition:

$$\beta[\Pi(\widehat{a}) - EF(\widehat{a})] + (1-\beta)\Pi(\overline{a}) - \Pi_0 - c\widehat{I} = 0, \tag{3}$$

where the second order condition is obviously satisfied. ■

3.3 Norm design

Having derived the optimal action and initiative chosen by the firm for given policy parameters, we now turn to the analysis of the design and enforcement of norms. As already claimed, in our setting, judges do not make errors given the evidence provided, and enforcement officials are loyal, reporting all the evidence they obtain. Hence, enforcement depends only on the resources E that the legislator assigns and on the availability of the evidence, with no discretionary role for judges and officials. The focus of the analysis is therefore on the choices of the legislator on the fines and the resources committed to enforcement.

The legislator influences the choices of the firm in two ways: by affecting the selection of the action a in case of successful learning, and by influencing the incentives to exert initiative effort I. The first effect, well known in the law and economics literature, captures *marginal deterrence*, that is, the law's ability to guide private choices among unlawful actions.[8] The second effect, which is not considered in traditional models of law enforcement, derives from the impact of the norm on initiative and therefore on the probability that any new action a will be taken. We label this second effect *average deterrence*. The legislator sets the policy parameters considering both effects on private choices and, ultimately, on welfare.

Starting with the marginal deterrence problem, since in general $w(\widehat{a}) \geqslant \underline{W}$ and $w' < 0$, the legislator will set the fine schedule so as to elicit the lowest possible $\widehat{a}$. In our example, the environmental agency induces firms to opt for the safest type of GM seeds that can be elicited. Given that the profit function $\Pi(a)$ is increasing, it is easy to show that, within the

[7] The second term is always positive, by equation (1): incomplete deterrence implies that the firm always gains from initiative.

[8] See the seminal work by Stigler (1970) and, for a more general treatment, Mookherjee and Png (1994).

sanctions that fulfill the principle of proportionality, we can focus on stepwise fine schedules such as:

$$F(w(a)) = F(a) = \begin{cases} \underline{F} & \text{if } a \leqslant \widetilde{a} \\ \overline{F} & \text{if } a > \widetilde{a} \end{cases}$$

We rely on Figure 2 to illustrate this point. The function $F(a)$ shifts the profit function $\Pi(a)$ downward by $\underline{F}$ to the left of point $\widetilde{a}$, and by $\overline{F}$ to its right, creating a local maximum at $\widetilde{a}$. The legislator wants to induce the firm to choose $\widetilde{a}$, that is to make $\widetilde{a}$ a global maximum, i.e. $\widetilde{a} = \widehat{a}$. This requires that

$$\Pi(\widetilde{a}) - E\underline{F} \geqslant \Pi(\overline{a}) - E\overline{F}.$$

Finally, among the global maxima $\widehat{a}$ the legislator will pick up the lowest action $\underline{\widehat{a}}$, in order to minimize social harm. We call $\underline{\widehat{a}}$ as the implemented action, that is implicitly defined by the equality

$$\Pi(\underline{\widehat{a}}) - E\underline{F} = \Pi(\overline{a}) - E\overline{F}, \tag{4}$$

or

$$\underline{\widehat{a}} = \Pi^{-1}[\Pi(\overline{a}) - E(\overline{F} - \underline{F})].$$

Figure 2 shows how the implemented action is identified.

[Insert Figure 2]

The figure also helps understanding why the fine schedule $F(a)$ is not the only one, among the non-decreasing schedules with codomain $\left[\underline{F}, \overline{F}\right]$, that can induce the action $\underline{\widehat{a}}$: any such function that penalizes action $\underline{\widehat{a}}$ with $\underline{F}$ and action $\overline{a}$ with $\overline{F}$ will induce the same choice. For example, the same result follows if actions below $\underline{\widehat{a}}$ are punished with $\underline{F}$ and those above it with a penalty that makes expected profits constant.

Notice that a higher enforcement effort E increases marginal deterrence:

$$\frac{\partial \underline{\widehat{a}}}{\partial E} = -\Pi^{-1\prime}[.](\overline{F} - \underline{F}) \leqslant 0, \tag{5}$$

and so does a wider range of fines, since:

$$\frac{\partial \underline{\widehat{a}}}{\partial \underline{F}} = \Pi^{-1\prime}[.]E \geqslant 0, \qquad \frac{\partial \underline{\widehat{a}}}{\partial \overline{F}} = -\Pi^{-1\prime}[.]E \leqslant 0. \tag{6}$$

Next, since the implemented action implies $\Pi(\underline{\widehat{a}}) - E\underline{F} = \Pi(\overline{a}) - E\overline{F}$, the expected profits at stage 2 can be written, after substituting, as:

$$\mathrm{E}(\Pi) = \Pi_0 + I[\overline{\Pi} - \Pi_0 - \beta E\overline{F}] - c\frac{I^2}{2},$$

so that

$$\widehat{I} = [\overline{\Pi} - \Pi_0 - \beta E\overline{F}]/c. \tag{7}$$

Hence, the optimal initiative is decreasing in both the enforcement effort E and the maximum fine $\overline{F}$:

$$\frac{\partial \widehat{I}}{\partial E} = -\frac{\beta \overline{F}}{c} \leqslant 0, \quad \frac{\partial \widehat{I}}{\partial \overline{F}} = -\frac{\beta E}{c} \leqslant 0,$$

and therefore is a continuous and decreasing function of enforcement activity. This is reminiscent of a result in contract theory proved by Aghion and Tirole (1997): the effort of the principal is a strategic substitute for that of the agent, if both efforts can concur to the solution of a decision problem. Likewise, here enforcement by officials depresses the initiative by firms. The difference is that in our setting the principal's effort cannot directly substitute for the firm's initiative.

We continue the analysis of the optimal policy considering three further steps: how the choice of enforcement E affects welfare; how the legislator chooses the optimal fines $\overline{F}$ and $\underline{F}$; and how the optimal policy changes in response to different probabilities of the social harm, β.

Expected welfare, conditional on the firm choosing the optimal initiative and the optimal implementable action, is:

$$\mathrm{E}(W) = W_0 + \widehat{I}(E, \overline{F})[\beta w(\widehat{\underline{a}}(E, \overline{F}, \underline{F})) + (1-\beta)\overline{W} - W_0] - [g(E) + c(\widehat{I}(E, \overline{F}))],$$

where the first term is the *status-quo* level of welfare, the second term:

$$\Delta \mathrm{E}(\widehat{W}) \equiv \beta w(\widehat{\underline{a}}) + (1-\beta)\overline{W} - W_0$$

is the expected welfare gain (or loss) stemming from initiative, and the last term captures the public and private costs of initiative. The optimal enforcement E^* is given by the legislator's first-order condition:[9]

$$\frac{\partial \mathrm{E}(W)}{\partial E} = \underbrace{[\Delta \mathrm{E}(\widehat{W}) - c\widehat{I}]\frac{\partial \widehat{I}}{\partial E}}_{\text{average deterrence } (+/-)} + \underbrace{\widehat{I}\beta w' \frac{\partial \widehat{\underline{a}}}{\partial E}}_{\text{marginal deterrence } (+)} - g' = 0. \tag{8}$$

This derivative has a nice interpretation. The first term captures the *average deterrence* of enforcement – the extent to which E discourages initiative, reducing the probability of

[9] The second derivative is negative:

$$\frac{\partial^2 \mathrm{E}(W)}{\partial E^2} = -c\left(\frac{\partial \widehat{I}}{\partial E}\right)^2 + 2\beta w' \frac{\partial \widehat{\underline{a}}}{\partial E}\frac{\partial \widehat{I}}{\partial E} + \widehat{I}\beta w' \frac{\partial \widehat{\underline{a}}^2}{\partial E^2} + \widehat{I}\beta w'' \frac{\partial \widehat{\underline{a}}^2}{\partial E^2} - g'' < 0.$$

In fact $w' < 0$ and $w'' \leqslant 0$ when the externality arises and $\frac{\partial \widehat{\underline{a}}^2}{\partial E^2} \geqslant 0$ thanks to $\Pi'' \leqslant 0$.

any new action, whether legal or not. This effect can be positive or negative, depending on whether private initiative has a positive or negative marginal social value $\Delta\mathrm{E}(\widehat{W}) - c\widehat{I}$.[10]

The second effect, instead, captures the *marginal deterrence* of enforcement – the extent to which enforcement affects the specific choice of actions when the latter generate social harm (which occurs with ex-ante probability $\widehat{I}\beta$). In contrast with average deterrence, the effect of marginal deterrence is always positive, because in the bad state welfare is assumed to be decreasing in the firm's actions ($w' < 0$) and the latter are curtailed by enforcement activity ($\partial\widehat{\underline{a}}/\partial E < 0$).

The last term of condition (8) is the marginal cost of deterrence. In an interior solution the optimal enforcement level equates the sum of average and marginal deterrence to its marginal cost. When private initiative is socially valuable, i.e. $\Delta\mathrm{E}(\widehat{W}) - c\widehat{I} > 0$, average deterrence calls for lower enforcement while marginal deterrence calls for higher enforcement. When the marginal social value of initiative is negative, i.e. $\Delta\mathrm{E}(\widehat{W}) - c\widehat{I} < 0$, both average and marginal deterrence require higher enforcement.

When private initiative is socially valuable, the enforcer faces a tradeoff: in setting the enforcement effort, he must balance the benefit of private initiative with the risk it entails. This tradeoff is reminiscent of the Hayekian idea that when private initiative is expected to be welfare-enhancing we would like to moderate public intervention so as to preserve private incentives.[11] When, instead, private initiative is ex-ante socially damaging, the trade-off vanishes: average and marginal deterrence work in the same direction, unambiguously requiring higher enforcement.

We now turn to the second step in our analysis. The following Lemma (proved in the Appendix) identifies the optimal fines:

Lemma 3 *The optimal fines are* $\underline{F} = F_{\min}$ *and* $\overline{F} = F_{\max}$.

When enforcement E^* is positive, the legislator will always set the minimum and maximum fines at the lowest and highest feasible levels, respectively: this yields the greatest effective marginal deterrence, for any given enforcement effort. This allows the legislator to save on costly enforcement, as in Becker (1968), in the sense that the lowest implementable

[10] If $\beta = 0$, then $\Delta\mathrm{E}(\widehat{W}) - c\widehat{I} = \overline{W} - W_0 - (\overline{\Pi} - \Pi_0) > 0$ by assumption (1), If instead $\beta = 1$, then $\Delta\mathrm{E}(\widehat{W}) - c\widehat{I} = w(\widehat{\underline{a}}) - W_0 - c\widehat{I} < 0$, because even the least damaging action $\underline{a}$ reduces welfare below the *status quo*: $w(\underline{a}) \leqslant W_0$, by assumption.

[11] Intuitively, the tradeoff arises from the fact that the regulator has too few instruments to influence firm's choices of innovation and actions: indeed one can show that the tradeoff disappears if the regulator is free to subsidize socially beneficial actions beside punishing socially harmful ones. (We thank Franck Portier for raising this point.) In our setting, we assume that such subsidies are unavailable either because of their budgetary costs or because they might create incentive for corrupt behavior by enforcers.

action $\widehat{\underline{a}}$ is obtained with the lowest amount of costly enforcement E. Average deterrence, instead, is unaffected by changes in the minimum penalty $\underline{F}$ and is raised by an increase in the maximum penalty $\overline{F}$, since learning investment is chosen taking the expected profits as a reference. This latter are always equal to the "outside option" $\overline{\Pi} - E\overline{F}$. For this reason, reducing punishment $\underline{F}$ for illegal actions up to $\widehat{\underline{a}}$ does not increase expected profits and does not reduce average deterrence.[12] On the contrary, increasing the maximum fine $\overline{F}$ reduces initiative $\widehat{I}$ and therefore raises average deterrence. It may appear surprising that, when the marginal social value of initiative is positive, it is optimal to set the maximum fine at the highest possible level, thereby discouraging initiative. This apparent paradox is explained by the legislator's ability to correct the disincentive effect of a larger fine with a lower enforcement intensity E^*.

We conclude our policy analysis by considering how the optimal policy changes with β, the probability that the innovation is socially harmful. To this purpose, let us define a value of β such that the corresponding optimal enforcement E^* is zero:

$$\beta_0(E = 0, \underline{F} = F_{\min}, \overline{F} = F_{\max}) : -[\Delta E(\widehat{W}) - c'(\widehat{I})]\frac{\partial \widehat{I}}{\partial E} = \widehat{I}\beta_0 w' \frac{\partial \widehat{\underline{a}}}{\partial E}. \quad (9)$$

Then one can characterize the optimal enforcement as follows (see the Appendix for the proof):

Lemma 4 *The optimal enforcement level E^* is zero if $\beta \in [0, \beta_0]$ and it is positive if $\beta \in (\beta_0, 1]$.*

When social harm is very unlikely, i.e. $\beta \in [0, \beta_0]$, even if the norm were to define welfare-reducing actions in A as illegal, it would be optimal not to enforce such a prohibition: $E^* = 0$. Anticipating that, the optimal norm prescribes that all the actions in A are legal ("laissez faire" or "per-se legality rule"). When instead the probability that the innovation is socially harmful is sufficiently high (($\beta \in (\beta_0, 1]$), then the optimal enforcement is positive: $E^* > 0$.

The following proposition summarizes the optimal design of norms characterized so far:

Proposition 5 *If $\beta \in [0, \beta_0]$, the regulator chooses a laissez-faire regime: fines are irrelevant because $E^* = 0$. If social harm is more likely ($\beta \in (\beta_0, 1]$), then the regulator chooses an effect-based norm that forbids actions when these are ex-post welfare-reducing, designs the fine schedule with the maximum possible flexibility ($\underline{F} = F_{\min}, \overline{F} = F_{\max}$), implements the lowest action $\widehat{\underline{a}}$ and enforces the policy optimally with $E^* > 0$.*

[12] Since the minimum fine $\underline{F}$ and the implemented action $\widehat{\underline{a}}$ are adjusted so as to leave the innovating firm's expected profits unchanged (and equal to its "outside option" $\overline{\Pi} - E\overline{F}$). Hence, a lower minimum fine $\underline{F}$ comes together with a less profitable (lower) implemented action $\widehat{\underline{a}}$, leaving net expected profits and the incentives to exert initiative unchanged.

3.4 Comparison with the first best

The first best outcome provides a useful benchmark for the previous results. In the first best, the legislator controls firms' choices directly without bearing any enforcement costs ($E = 0$). The welfare-maximizing action is $\overline{a}$ in the good state and a_0 in the bad state, so that expected welfare is

$$\mathrm{E}(W) = W_0 + I(1-\beta)(\overline{W} - W_0) - c\frac{I^2}{2}.$$

The first-order condition with respect to I yields the optimal investment

$$\widehat{I}^{FB} = \frac{(1-\beta)(\overline{W} - W_0)}{c}. \tag{10}$$

To compare $\widehat{I}^{FB}$ with the equilibrium investment level $\widehat{I}(E, \overline{F})$ obtained in (7), notice that $\overline{W} - W_0 > \overline{\Pi} - \Pi_0 > \overline{F}$ by assumption, so that when β is close to 0 (the bad state is very unlikely) we have underinvestment: $\widehat{I}^{FB} > \widehat{I}$. Since in this environment I is chosen according to private benefits while its social benefits are larger, investment is below the first best. By the same token, when β is close to 1 (the bad state is very likely) we obtain overinvestment: $\widehat{I}^{FB} < \widehat{I}$. In this case, social benefits are below private ones, and the firm chooses excessive investment. Hence, our model produces underinvestment or overinvestment depending on the likelihood of social harm.

3.5 Comparison with the traditional model

It is interesting to compare the results obtained so far with a setting where firms could implement the actions in A without any investment in learning, as in the traditional model of law enforcement where the choice between actions requires no previous initiative effort. Such a firm would choose the same actions that, according to Lemma 1, a firm chooses under successful learning, that is, $\widehat{\underline{a}}$ if the innovation is socially harmful and $\overline{a}$ otherwise. In this setting, social welfare would be

$$\mathrm{E}(W) = [\beta w(\widehat{\underline{a}}(E, \underline{F}, \overline{F})) + (1-\beta)\overline{W}] - g(E),$$

and therefore optimal enforcement would be given by[13]

$$\frac{\partial \mathrm{E}(W)}{\partial E} = \underbrace{\beta w' \frac{\partial \widehat{\underline{a}}}{\partial E}}_{\text{marginal deterrence } (+)} - g' = 0,$$

[13] The second derivative is negative:

$$\frac{\partial^2 \mathrm{E}(W)}{\partial E^2} = \alpha w' \frac{\partial \widehat{\underline{a}}^2}{\partial E^2} + \alpha w'' \frac{\partial \widehat{\underline{a}}}{\partial E} - g'' < 0.$$

In fact $w' < 0$ and $w'' \leqslant 0$ when the externality arises and $\frac{\partial \widehat{\underline{a}}^2}{\partial E^2} \geqslant 0$ thanks to $\Pi'' \leqslant 0$.

$$\frac{\partial \mathrm{E}(W)}{\partial \overline{F}} = \widehat{I}\beta w' \frac{\partial \widehat{a}}{\partial \overline{F}} \geqslant 0,$$
$$\frac{\partial \mathrm{E}(W)}{\partial \underline{F}} = \widehat{I}\beta w' \frac{\partial \widehat{a}}{\partial \underline{F}} < 0.$$

Clearly, in this case regulation affects private incentives only through marginal deterrence, and enforcement is always positive if the innovation is socially harmful: since $g'(0) = 0$, it is evident that $E^* > 0$ for $\beta \in (0, 1]$. Moreover, maximum flexibility is clearly optimal also in this case: $\underline{F} = F_{\min}$ and $\overline{F} = F_{\max}$. The following Lemma states the different scope of "per-se legality rules" in the two cases:

Lemma 6 *If new actions require no initiative effort, then the laissez-faire regime is optimal only if no social harm can occur ($\beta = 0$). If instead new actions require initiative effort, then the laissez-faire regime is optimal also when social harm occurs with a positive small probability, i.e. $\beta \in [0, \beta_0]$.*

[Insert Figure 3]

Figure 3 illustrates how the optimal policy changes with the probability of the bad state, β, in our as well as in the traditional model. The comparison helps to understand the role of initiative in shaping public intervention: when private investment in learning and innovation is an important piece of the story, the optimal design of norms requires to limit the intervention by opting for the laissez-faire regime in a wider set of circumstances ($\beta \in [0, \beta_0]$). It is optimal to sacrifice marginal deterrence to preserve high initiative when its marginal social value is sufficiently high.

4 Corrupt officials

In the setting considered so far, enforcement officials collect evidence on the firms' conduct and on the welfare effects of their actions, truthfully reporting these facts to a judge who decides on the penalty according to a given fine schedule. Since enforcement officials could always be relied on to report their evidence truthfully, we could analyze policy design without distinguishing between legislator and enforcers.

In this section, instead, we consider the agency problems that may arise in enforcement, by exploring how the design and enforcement of norms is affected when enforcement officials are self-interested and uncommitted to truthful reporting. We denote the official's report on the firm's action by $r = r(a) \in A$. We maintain the previous setup, assuming that the legislator chooses both the enforcement effort E (the resources of the agency), the range of fines $[\underline{F}, \overline{F}]$ within the admissible range $[F_{\min}, F_{\max}]$ and a fine schedule obeying the principle of proportionality. In this setting, we explicitly recognize that the fine paid by the firm depends on the reported action r, that is $F(r) \in \left[\underline{F}, \overline{F}\right]$. This notation encompasses the case of faithful officials examined in previous sections as a special case where $r = a$, so that $F = F(a)$.

When officials are self-interested, they may extract rents from firms to misreport evidence about their conduct. By misreporting the firms' true actions, they can let the firm pay a lower fine than the statutory one in exchange for a bribe. More specifically, we assume that while the judge can directly recognize the lawful action a_0, he cannot distinguish among the new actions $a \in A$ and has to rely on the report r by the enforcement official. The latter cannot lie to the judge about the true state of nature s, but only on the action taken by the firm: the enforcer can lie on the finer pieces of information but not on the bolder ones. Moreover, we assume that he cannot submit a false report $r \neq a$ that damages the firm: if he did, the firm would be able to rebut the false report by providing counter evidence. This "no blackmail" assumption implies that, if there is social harm, the official cannot report an offence that is more serious than the real one, i.e. an action $r > a$.

When he discovers that the firm's innovation is socially harmful, the official reports an action $r < a$ (less severely sanctioned than the real one) if he is offered a bribe B greater than a minimum bribe $\underline{B} \geqslant 0$; otherwise, he reports truthfully. The "reservation bribe" $\underline{B}$, which will turn out to be a key parameter in the analysis, depends on the honesty of the official, as well as on the sanctions for corrupt officials.

The new timing of the model is as follows: at time 1 the legislator writes the norm, specifies the minimum fine $\underline{F} \in \left[F_{\min}, \overline{F}\right]$ and the maximum fine $\overline{F} \in [\underline{F}, F_{\max}]$, sets the enforcement effort E and designs the fine schedule $F(r)$. At time 2 the official sets the bribe B to be requested from firms with socially harmful innovations in exchange for the report $r(a)$. At time 3 the firm exerts learning effort I. At time 4 it takes the action, given the outcome of its learning process. Finally, at time 5 actions produce their private payoffs Π and their social consequences W; the official obtains evidence with probability E, files a report r and possibly takes a bribe B in exchange for misreporting; conditioning on the official's report, the judge levies the fine $F(r)$.[14]

4.1 Firm actions

As in the benchmark model, we proceed by solving the game backward, starting from stage 4 in which the firm chooses its action. When the new actions are harmful to society ($s = b$),

[14] This timing implicitly assumes that at stage 2 the official commits to a given bribe B before the choices of the firm are made. However, it can be shown that the results of this section would be qualitatively unchanged if the bribe were set after the firm moves, provided the firm has some bargaining power in negotiating the bribe.

the firm has the following alternatives:

(i) not pay the bribe, so that the official reports truthfully ($r = a$), and choose the most profitable action $\widehat{a}^{nb}$, defined by

$$\widehat{a}^{nb} = \arg\max_{a \in A} [\Pi(a) - EF(a)],$$

(ii) pay the bribe B (so that the official reports $r(a) < a$) and select the most profitable action $\widehat{a}^{b}$ such that

$$\widehat{a}^{b} = \arg\max_{a \in A} \left\{ \Pi(a) - E\left[F(r(a)) + B\right] \right\}.$$

If the firm chooses the first course of action, its anticipated profits are net of the expected fine; if it chooses the second, they are also net of the expected bribe. The following Lemma characterizes the optimal actions chosen in each contingency:

Lemma 7 *At stage 4, given E, $F(r)$, $r(a)$ and B, the firm:*

- *chooses action a_0 if learning is unsuccessful;*
- *chooses action $\overline{a}$ and does not pay any bribe if learning is successful and new actions are not socially harmful ($s = g$);*
- *chooses action $\widehat{a}^{b}$ and pays bribe B if learning is successful, new actions are socially harmful ($s = b$) and $\Pi(\widehat{a}^{nb}) - EF(\widehat{a}^{nb}) < \Pi(\widehat{a}^{b}) - E\left[F(r(\widehat{a}^{b})) + B\right]$;*
- *chooses action $\widehat{a}^{nb}$ and does not pay any bribe if learning is successful, new actions are socially harmful ($s = b$) and $\Pi(\widehat{a}^{nb}) - EF(\widehat{a}^{nb}) \geqslant \Pi(\widehat{a}^{b}) - E\left[F(r(\widehat{a}^{b})) + B\right]$.*

Therefore, it is only when new actions are socially harmful that the firm's behavior differs from that which was analyzed in the previous sections (see Lemma 1). In the present case, the firm's choice of action does not depend only on the policy variables $F(r)$ and E, as in the benchmark model, but also on the possibility of paying the bribe B to the official in exchange for his report $r(a)$.

4.2 Firm initiative

At stage 3 the firm chooses its initiative, given the optimal actions to be chosen at stage 4, the enforcement policy $F(r)$ and E chosen by the legislator, and the bribe B and the reporting schedule $r(a)$ chosen by the official. The firm's expected profits are:

$$\mathrm{E}(\Pi) = \Pi_0 + I\left\{\beta \max\left[\Pi(\widehat{a}^{nb}) - EF(\widehat{a}^{nb}),\ \Pi(\widehat{a}^{b}) - E\left(F(r(\widehat{a}^{b})) + B\right)\right] + (1-\beta)\overline{\Pi} - \Pi_0\right\} - c\frac{I^2}{2}. \tag{11}$$

This expression differs from the earlier expression (2) only by the term in square brackets, which is the payoffs obtained when the initiative is successful and the new actions are socially harmful. In this case, the firm must choose between the best action that it can pick without bribing the official and its best action conditional on bribing the official.

The optimal initiative $\widehat{I}^c$, where the superscript c refers to corruption, is described in the following Lemma.

Lemma 8 *At stage 3, given E , $F(r)$, $r(a)$ and B, the optimal level of initiative is*

$$\widehat{I}^c = \frac{\beta \max \left[\Pi(\widehat{a}^{nb}) - EF(\widehat{a}^{nb}),\ \Pi(\widehat{a}^{b}) - E\left(F(r(\widehat{a}^{b})) + B\right)\right] + (1-\beta)\overline{\Pi} - \Pi_0}{c}.$$

Proof. The result follows immediately from the first order condition. ■

4.3 Bribe and official's report

At stage 2 the official sets the bribe that he requests in exchange for misreporting, that is for reporting an action $r(a) < a$, given the policy variables set by the legislator. Clearly, for misreporting not to be detectable, the misreported action must be the same as the action optimally chosen by the firm in the absence of bribing: $r(\widehat{a}^b) = r(\widehat{a}^{nb}) = \widehat{a}^{nb}$. We assume that the equilibrium bribe $\widehat{B}$ is determined as the outcome of Nash bargaining between the firm and the official, where the firm's and the official's bargaining power are γ and $1-\gamma$, respectively. The following Lemma identifies the optimal bribe $\widehat{B}$ and reporting $\widehat{r}(a)$:

Lemma 9 *Given E and $F(a)$, an official takes a bribe*

$$\widehat{B} = \underline{B} + (1-\gamma)\left[\frac{\overline{\Pi} - \Pi(\widehat{a}^{nb})}{E} - \underline{B}\right] > \underline{B} \tag{12}$$

in exchange for reporting $r(a) = \widehat{a}^{nb}$ for any $a > \widehat{a}^{nb}$. He does not take any bribe and reports truthfully if $\widehat{B} \leqslant \underline{B}$.

Proof. The Nash bargaining problem for B is:

$$\max_B \left[\Pi(\widehat{a}^b) - \Pi(\widehat{a}^{nb}) - E\left(F(r(\widehat{a}^b)) - F(\widehat{a}^{nb}) + B\right)\right]^\gamma [EB - E\underline{B}]^{1-\gamma},$$

which is solved by

$$\widehat{B} = \gamma\underline{B} + (1-\gamma)\left\{\frac{\Pi(\widehat{a}^b) - \Pi(\widehat{a}^{nb})}{E} - \left[F(r(\widehat{a}^b)) - F(\widehat{a}^{nb})\right]\right\}.$$

Taking into account that $r(\widehat{a}^b) = r(\widehat{a}^{nb}) = \widehat{a}^{nb}$, the solution becomes

$$\widehat{B} = \gamma\underline{B} + (1-\gamma)\frac{\Pi(\widehat{a}^b) - \Pi(\widehat{a}^{nb})}{E}.$$

The official will accept the bribe $\widehat{B}$ provided it exceeds $\underline{B}$. Moreover, to maximize his bribe, the official will be ready to misreport any action above $\widehat{a}^{nb}$. By doing so, he will induce the firm to choose the worst possible action, that is, $\widehat{a}^{b} = \overline{a}$, since this pushes its profit $\Pi(\widehat{a}^{b})$ to the maximal level $\overline{\Pi}$. By using this fact and rearranging, one obtains (12). ■

Note that the misreporting schedule optimally chosen by the official when he takes the bribe induces the firm to choose the worst possible action $\overline{a}$, since this is the action that maximizes the gains from corruption.

The equilibrium bribe (12) has a simple interpretation: to misreport, the official must obtain a premium over and above his reservation bribe $\underline{B}$, and this premium is a share $1-\gamma$ (his bargaining power) of the net increase in the joint net surplus that both parties derive from misreporting (the expression in square brackets).[15] For the inequality in (12) to hold, this premium must be positive: in other words, bribing occurs only if:

$$\overline{\Pi} - \Pi(\widehat{a}^{nb}) - E\underline{B} > 0. \tag{13}$$

It is up to the legislator to prevent this condition from being met, by implementing the appropriate action $\widehat{a}^{nb}$ through the design of the fine schedule. This leads us to stage 1 of the game.

4.4 Norm design

At stage 1, the legislator sets the policy variables so as to maximize welfare, taking into account the subsequent self-interested behavior of officials. He anticipates that by affecting the implementable action $\widehat{a}^{nb}$, he modifies the rents from misreporting and thereby the maximum bribe that the official will be able to request. For the legislator, it is always optimal to induce the action $\widehat{a}^{nb}$ rather than $\widehat{a}^{b} = \overline{a}$ (when the bribe is paid).

As in the benchmark model, we can restrict our analysis to stepwise fine schedules: the implemented action will occur at the point of discontinuity in the schedule, so that lower actions are sanctioned with the minimum fine $\underline{F}$ and higher actions with the maximum fine $\overline{F}$. The optimal implementable action $\widehat{a}^{nb} = \widehat{\underline{a}}^{c}$ is the lowest action that makes the bribe unattractive, that is, induces inequality (13) to fail:

$$\overline{\Pi} - \Pi(\widehat{\underline{a}}^{c}) = E\underline{B}, \tag{14}$$

which implies

$$\widehat{\underline{a}}^{c} = \Pi^{-1}\left[\overline{\Pi} - E\underline{B}\right]. \tag{15}$$

[15] This joint net surplus is the increase in the firm's profits minus the disutility incurred by the official when misreporting ($-\underline{B}$).

Therefore, the action that the legislator can induce depends on the enforcement effort and on the corruptibility of officials. A greater enforcement E and a higher reservation bribe $\underline{B}$ allow the legislator to implement a less harmful action:

$$\frac{\partial \widehat{\underline{a}}^c}{\partial E} = -\Pi^{-1\prime}[.]\underline{B} \leqslant 0 \text{ and } \frac{\partial \widehat{\underline{a}}^c}{\partial \underline{B}} = -\Pi^{-1\prime}[.]E \leqslant 0. \tag{16}$$

When $\underline{B} = 0$, i.e. when the official is ready to accept even a negligible bribe in order to misreport, then $\widehat{\underline{a}}^c = \overline{a}$, implying that marginal deterrence is completely lost. On the contrary, when $\underline{B} \geqslant \overline{F} - \underline{F}$ we are back to the benchmark case of loyal officials and the implementable action is $\widehat{\underline{a}}$. Officials are corruptible but their reservation bribe is so high that the incentive constraint to avoid the payment of a bribe never binds. Moreover, the optimal implementable action $\widehat{\underline{a}}^c$ does not depend either on the minimum fine $\underline{F}$ (which is paid regardless of whether the firm pays the bribe) or on the relative bargaining power γ (which affects only the split of the surplus from misreporting, not its total size).

The optimal fine schedule that leads the firm to prefer action $\widehat{\underline{a}}^c$ (without paying any bribe) to action $\overline{a}$ (when paying the bribe), implicitly excludes that the firm might prefer a third option: choosing the most profitable illegal action $\overline{a}$ and, if caught, instead of paying the bribe, paying the full fine $\overline{F}$. But the firm will never take this option, since $\widehat{a}^{nb}$ is defined as the action that gives the highest net profits, i.e. $\Pi(\widehat{a}^{nb}) - E\underline{F} \geqslant \overline{\Pi} - E\overline{F}$.

Equation (14) implies a restriction on the range of fines that the legislator can use in designing the optimal fine schedule. We can see that upon subtracting $E\underline{F}$ from both sides and rearranging, equation (14) can be rewritten as

$$\Pi(\widehat{\underline{a}}^c) - E\underline{F} = \overline{\Pi} - E(\underline{F} + \underline{B}).$$

This equality, jointly with the condition $\Pi(\widehat{a}^{nb}) - E\underline{F} \geqslant \overline{\Pi} - E\overline{F}$, yields

$$\Pi(\widehat{\underline{a}}^c) - E\underline{F} = \overline{\Pi} - E(\underline{F} + \underline{B}) \geqslant \overline{\Pi} - E\overline{F},$$

implying that

$$\overline{F} - \underline{F} \geqslant \underline{B}. \tag{17}$$

So the official's reservation bribe $\underline{B}$ determines the range of fines (17) consistent with the incentive constraint, as well as marginal deterrence (as shown by (15)).

Now we can rewrite the expression for the expected profits (11) in a simpler fashion. Using the equilibrium values $F(\widehat{a}^{nb}) = F(r(\widehat{a}^b)) = \underline{F}$, $\Pi(\widehat{a}^b) = \overline{\Pi}$, $\Pi(\widehat{a}^{nb}) = \Pi(\widehat{\underline{a}}^c)$ and exploiting the equality in (14), expected profits become:

$$\mathrm{E}(\Pi) = \Pi_0 + I[\overline{\Pi} - \beta E(\underline{F} + \underline{B}) - \Pi_0] - c\frac{I^2}{2},$$

yielding the following expression for the optimal initiative level chosen by the firm:

$$\widehat{I}^c = \frac{\overline{\Pi} - \beta E(\underline{F} + \underline{B}) - \Pi_0}{c}.$$

Hence, the optimal initiative depends, as in the benchmark model, on the "outside-option" profits, which in the case of corrupt officials, are those obtained upon paying the bribe. The optimal initiative is decreasing in enforcement E, in the minimum fine $\underline{F}$ and in the reservation bribe $\underline{B}$:

$$\frac{\partial \widehat{I}^c}{\partial E} = -\frac{\beta(\underline{F} + \underline{B})}{c} < 0, \qquad \frac{\partial \widehat{I}^c}{\partial \underline{F}} = -\frac{\beta E}{c} \leqslant 0 \quad \text{and} \quad \frac{\partial \widehat{I}^c}{\partial \underline{B}} = -\frac{\beta E}{c} \leqslant 0. \tag{18}$$

Therefore, the reservation bribe has a similar effect to that of an increase in enforcement or fines: if officials are less corruptible, inducing them to misreport would require a higher bribe, which reduces the equilibrium net profit of firms and therefore depresses their initiative.

We continue the analysis of the optimal policy considering three further steps: How the choice of enforcement E affects welfare; how the legislator chooses the optimal fines $\overline{F}$ and $\underline{F}$; and finally, how the optimal policy changes in response to different reservation bribes $\underline{B}$.

Expected welfare, conditional on the optimal implementable action $\widehat{\underline{a}}^c$ and initiative $\widehat{I}^c$, is:

$$\mathrm{E}(W^c) = W_0 + \widehat{I}^c(E, \underline{F}, \underline{B})[\beta w(\widehat{\underline{a}}^c(E, \underline{B})) + (1-\beta)\overline{W} - W_0] - [g(E) + c(\widehat{I}^c(E, \underline{F}, \underline{B}))].$$

Therefore, the optimal effort choice is:[16]

$$\frac{\partial \mathrm{E}(W^c)}{\partial E} = \underbrace{[\Delta \mathrm{E}(\widehat{W^c}) - c\widehat{I}^c]\frac{\partial \widehat{I}^c}{\partial E}}_{\text{average deterrence } (\,+\,/\,-\,)} + \underbrace{\widehat{I}^c \beta w' \frac{\partial \widehat{\underline{a}}^c}{\partial E}}_{\text{marginal deterrence } (+)} - g' = 0, \tag{19}$$

where $\Delta \mathrm{E}(\widehat{W^c}) \equiv \beta w(\widehat{\underline{a}}^c) + (1-\beta)\overline{W} - W_0$ is the expected change in welfare relative to the *status quo* if the initiative is successful, while the term in square brackets measures the marginal social value of initiative.

In equation (19), the first term captures average deterrence. As before, this effect can be negative or positive, depending on whether initiative has a positive or a negative marginal social value. The second term corresponds to the marginal deterrence effect, and it is positive if $\underline{B} > 0$, since a higher enforcement effort E allows to implement a lower action, i.e. a socially better one.

[16] The second derivative is negative:

$$\frac{\partial^2 \mathrm{E}(W^c)}{\partial E^2} = -c\left(\frac{\partial \widehat{I}^c}{\partial E}\right)^2 + 2\beta w' \frac{\partial \widehat{\underline{a}}^c}{\partial E}\frac{\partial \widehat{I}^c}{\partial E} + \widehat{I}^c \beta w' \frac{\partial \widehat{\underline{a}}^{c2}}{\partial E^2} + \widehat{I}^c \beta w'' \frac{\partial \widehat{\underline{a}}^{c2}}{\partial E^2} - g'' < 0.$$

In fact $w' < 0$ and $w'' \leqslant 0$ when the externality arises and $\frac{\partial \widehat{\underline{a}}^{c2}}{\partial E^2} \geqslant 0$ thanks to $\Pi'' \leqslant 0$.

Now we turn to the second step in our analysis, identifying the optimal fines. Let us define, consistently with our analysis of the benchmark model, a level of the probability of the bad state, β_0^c, such that $\frac{\partial E(W^c)}{\partial E} = 0$ when $E = 0$. In addition, let us also define a second threshold level, $\underline{\beta}_0^c$, such that the marginal social value is zero: $\Delta \mathrm{E}(\widehat{W}^c) - c\widehat{I}^c = 0$. The following Lemma (proved in the Appendix) establishes the relationship between the two thresholds:

Lemma 10 $0 < \beta_0^c < \underline{\beta}_0^c < 1$.

Equipped with these two thresholds, we can now analyze the level of fines chosen within the available range $[F_{\min}, F_{\max}]$. Notice that the minimum fine $\underline{F}$ influences the level of initiative $\widehat{I}^c$ but not the implementable action $\underline{\widehat{a}}^c$. Hence, setting the minimum fine affects average deterrence but not marginal deterrence. Indeed, we have:

$$\frac{\partial \mathrm{E}(W^c)}{\partial \underline{F}} = \underbrace{[\Delta \mathrm{E}(\widehat{W}^c) - c\widehat{I}^c]\frac{\partial \widehat{I}^c}{\partial \underline{F}}}_{\text{average deterrence } (+/-)}$$

When the marginal social value of initiative and the optimal enforcement E^* are positive, i.e. in the interval $\beta \in \left(\beta_0^c, \underline{\beta}_0^c\right]$, this derivative is negative and it is optimal to set

$$\underline{F} = F_{\min}.$$

The maximum fine, in this case, is defined by the constraint $\overline{F} - \underline{F} \geqslant \underline{B}$, which implies

$$\overline{F} \in [F_{\min} + \underline{B}, F_{\max}] .$$

For higher values of the probability of the bad state, i.e. for $\beta > \underline{\beta}_0^c$ we have $\Delta \mathrm{E}(\widehat{W}^c) - c\widehat{I}^c < 0$, implying $\frac{\partial \mathrm{E}(W^c)}{\partial \underline{F}} > 0$. In this case the legislator will want to raise the minimum fine as much as possible, in order to discourage initiative. This, together with the constraint $\overline{F} - \underline{F} \geqslant \underline{B}$, requires the maximum fine to be as high as possible and such that $\overline{F} - \underline{F} = \underline{B}$. The optimal fines then are:

$$\overline{F} = F_{\max} \text{ and } \underline{F} = F_{\max} - \underline{B}.$$

These fines, and the actions that they induce, are illustrated in Figure 4. The figure shows that the action implemented with corrupt officials, $\underline{\widehat{a}}^c$, exceeds (for given enforcement) and therefore is worse than the action that would be implemented with loyal officials, $\underline{\widehat{a}}$, which is the same as shown in Figure 2. So the corruptibility of enforcement officials reduces the welfare level that the legislator can hope to achieve.

[Insert Figure 4]

We can summarize the above discussion in the following Proposition, which is illustrated in Figure 5:

Proposition 11 *If $\beta \in [0, \beta_0^c]$ the regulator chooses a laissez-faire regime and fines are irrelevant. If social harm is more likely ($\beta \in \left(\beta_0^c, \underline{\beta}_0^c\right]$), the regulator chooses an effect-based norm that forbids ex-post welfare-reducing actions, designs the fine schedule with the greatest possible flexibility ($\underline{F} = F_{\min}, \overline{F} = F_{\max}$), implements the lowest action $\widehat{\underline{a}}^c$ and enforces the policy optimally with $E^c > 0$. When social harm is even more likely ($\beta \in \left(\underline{\beta}_0^c, 1\right]$), the legislator reduces the flexibility of the norm by setting $\overline{F} = F_{\max}$ and $\underline{F} = F_{\max} - \underline{B}$.*

[Insert Figure 5]

The previous Proposition shows that, when innovation is very likely to result in socially harmful actions, the legislator must respond to a decrease in the reservation bribe $\underline{B}$ (less loyal officials) by raising the minimum fine and thereby restricting the range of fines, in contrast with what was found for the case with loyal enforcers (where the range of fines is always maximal: see Lemma 3). The following Corollary summarizes these results:

Corollary 12 *A decrease in enforcers' loyalty ($\underline{B}$) raises the minimum fine $\underline{F} = F_{\max} - \underline{B}$ and reduces the norm's flexibility ($\overline{F} - \underline{F} = \underline{B}$).*

5 Conclusion

In this paper we study the design and enforcement of norms that apply to private actions made possible by innovative activity, that we label as "private initiative". We highlight their effects not only on the choices of private agents but also on the very incentives to innovate. We consider effect-based norms, that is, norms which penalize actions on the basis of their ex-post effects on welfare. The flexibility of norms depends on the possibility of assigning different fines to different actions, i.e. on the range of fines admitted.

Initially we develop the model under the assumption that law enforcers are loyal. In this case, when the new actions are socially harmful, the fine schedule induces firms to select a less harmful action than they would have done otherwise (marginal deterrence). Enforcement by the regulator makes marginal deterrence more effective and reduces the expected profits of firms, and therefore their initiative (average deterrence). This is desirable if, in expected terms, initiative reduces welfare, i.e. if social harm is relatively likely. But if initiative is ex-ante welfare enhancing, then the effects of enforcement effort via marginal and average deterrence work in opposite directions. So the legislator will choose a laissez-faire regime if the marginal social value of initiative is positive and sufficiently large, i.e. if social harm is unlikely, and a flexible norm otherwise. Indeed in the latter case maximizing the range of fines (choosing a flexible norm) sharpens marginal deterrence without reducing average deterrence.

When we abandon the assumption of loyal enforcers, that is, consider officials who can misreport the action observed in exchange for a bribe, marginal deterrence is reduced. When social harm is sufficiently likely, in order to prevent the firm from paying a bribe and take the worst action, the legislator must become less ambitious in designing regulation: he must accept that the firm carries out a more profitable and socially damaging action. Another consequence of corruption is that the legislator must compress the fine schedule by increasing the minimum fine, thereby reducing both the flexibility of the law and the private incentives to innovate.

Appendix

Proof of Lemma 3. The first order conditions in the complete optimal policy program are:

$$\frac{\partial \mathrm{E}(W)}{\partial \overline{F}} = [\Delta \mathrm{E}(\widehat{W}) - c\widehat{I}]\frac{\partial \widehat{I}}{\partial \overline{F}} + \widehat{I}\beta w' \frac{\partial \widehat{\underline{a}}}{\partial \overline{F}} \geqslant 0 \tag{20}$$

$$\frac{\partial \mathrm{E}(W)}{\partial \underline{F}} = \widehat{I}\beta w' \frac{\partial \widehat{\underline{a}}}{\partial \underline{F}} < 0 \tag{21}$$

$$\frac{\partial \mathrm{E}(W)}{\partial E} = [\Delta \mathrm{E}(\widehat{W}) - c\widehat{I}]\frac{\partial \widehat{I}}{\partial E} + \widehat{I}\beta w' \frac{\partial \widehat{\underline{a}}}{\partial E} - g' \leqslant 0 \tag{22}$$

Recall that: $\frac{\partial \widehat{\underline{a}}}{\partial E} = -\Pi^{-1\prime}[.](\overline{F} - \underline{F}) \leqslant 0$, $\frac{\partial \widehat{\underline{a}}}{\partial \underline{F}} = \Pi^{-1\prime}[.]E \geqslant 0$, $\frac{\partial \widehat{\underline{a}}}{\partial \overline{F}} = -\Pi^{-1\prime}[.]E \leqslant 0$, $\frac{\partial \widehat{I}}{\partial E} = -\frac{\beta \overline{F}}{c} \leqslant 0$, $\frac{\partial \widehat{I}}{\partial \overline{F}} = -\frac{\beta E}{c} \leqslant 0$.

If $E = 0$ $\frac{\partial \widehat{I}}{\partial \overline{F}} = \frac{\partial \widehat{\underline{a}}}{\partial \overline{F}} = \frac{\partial \widehat{\underline{a}}}{\partial \underline{F}} = 0$ then $\overline{F}$ and $\underline{F}$ are indeterminate.

We want to check if for values of β such that $E^* > 0$ $\overline{F}$ and $\underline{F}$ can assume interior values.

i) For $\underline{F}$, this is false, given that the first order condition with respect to $\underline{F}$ is always negative.

ii) For $\overline{F}$, substitute $\frac{\partial \widehat{I}}{\partial \overline{F}}$, $\frac{\partial \widehat{\underline{a}}}{\partial \overline{F}}$, $\frac{\partial \widehat{I}}{\partial E}$ and $\frac{\partial \widehat{\underline{a}}}{\partial E}$in the first order conditions to get:

$$\frac{\partial \mathrm{E}(W)}{\partial \overline{F}} = [\Delta \mathrm{E}(\widehat{W}) - c\widehat{I}]\left(-\frac{\beta E}{c}\right) + \widehat{I}\beta w'\left(-\Pi^{-1\prime}[.]E\right) \geqslant 0 \tag{23}$$

$$\frac{\partial \mathrm{E}(W)}{\partial E} = [\Delta \mathrm{E}(\widehat{W}) - c\widehat{I}]\left(-\frac{\beta \overline{F}}{c}\right) + \widehat{I}\beta w'\left(-\Pi^{-1\prime}[.](\overline{F})\right) - g' = 0 \tag{24}$$

where both conditions are evaluated at the same $\widehat{I}$, $\widehat{\underline{a}}$, $\underline{F} = 0$, E^* and $\overline{F}$.

Rewrite the first-order conditions to get:

$$\frac{\partial \mathrm{E}(W)}{\partial \overline{F}} = E\left\{[\Delta \mathrm{E}(\widehat{W}) - c\widehat{I}]\left(-\frac{\beta}{c}\right) + \widehat{I}\beta w'\left(-\Pi^{-1\prime}[.]\right)\right\} \geqslant 0 \tag{25}$$

$$\frac{\partial \mathrm{E}(W)}{\partial E} = \overline{F}\left\{[\Delta \mathrm{E}(\widehat{W}) - c\widehat{I}]\left(-\frac{\beta}{c}\right) + \widehat{I}\beta w'\left(-\Pi^{-1\prime}[.]\right)\right\} - g' \leqslant 0 \tag{26}$$

Assume $E^* > 0$. Then $g' = \overline{F}\left\{[\Delta \mathrm{E}(\widehat{W}) - c\widehat{I}]\left(-\frac{\beta}{c}\right) + \widehat{I}\beta w'\left(-\Pi^{-1\prime}[.]\right)\right\}$. For $E^* > 0$ we have $g' > 0$ and this, together with $\overline{F} > 0$, implies $\left\{[\Delta \mathrm{E}(\widehat{W}) - c\widehat{I}]\left(-\frac{\beta}{c}\right) + \widehat{I}\beta w'\left(-\Pi^{-1\prime}[.]\right)\right\} > 0$. Next, $E^* > 0$ and $\left\{[\Delta \mathrm{E}(\widehat{W}) - c\widehat{I}]\left(-\frac{\beta}{c}\right) + \widehat{I}\beta w'\left(-\Pi^{-1\prime}[.]\right)\right\} > 0$ imply $\frac{\partial \mathrm{E}(W)}{\partial \overline{F}} > 0$. In other words, $\overline{F}$ is always equal to $F_{\max}$ when $E^* > 0$.

Finally, since the only interior solution in the program is for E^*, the second order conditions are satisfied given $\frac{\partial^2 \mathrm{E}(W)}{\partial E^2} < 0$. ■

Proof of Lemma 4. When $\beta = 0$ the first term in (8) is negative, given (1); the second term is zero and the third is negative. Hence, we have a corner solution at $E^* = 0$. When $\beta = 1$, then both the first and second terms of (8) are positive, and the third must therefore be negative. Hence, $\partial \mathrm{E}(W)/\partial E = 0$ implies an interior solution with $E^* > 0$.

Notice that given the definition of β_0, when $E = 0$ and the fines are optimally set at $\underline{F} = F_{\min}, \overline{F} = F_{\max}$ the first two terms in (8) cancel out and, given that $g'(0) = 0$ by assumption, $\partial \mathrm{E}(W)/\partial E = 0$ at $E^* = 0$. In other words, β_0 is defined consistently with the optimal policy program, which implies at β_0 an interior solution with $E^* = 0$.

Next, we want to show that β_0 is unique. First, since we have just shown that $E^* = 0$ for $\beta = 0$ and $E^* > 0$ for $\beta = 1$, then a unique interior β_0 would feature $\left.\frac{dE^*}{d\beta}\right|_{\beta_0} > 0$. If instead there were multiple β_0's, we would obtain an internal solution $E^* = 0$ for each of these different β_0's. But if this were true, then $\left.\frac{dE^*}{d\beta}\right|_{\beta_0} < 0$ for at least some β_0. Now remember that

$$\frac{dE^*}{d\beta} = -\frac{\frac{\partial^2 \mathrm{E}(W)}{\partial E \partial \beta}}{\frac{\partial^2 \mathrm{E}(W)}{\partial E^2}}.$$

Since $\frac{\partial^2 \mathrm{E}(W)}{\partial E^2} < 0$ due to the second order conditions, $sign \frac{dE^*}{d\beta} = sign \frac{\partial^2 \mathrm{E}(W)}{\partial E \partial \beta}$. Note that, evaluated at $E = 0$, the latter derivative is

$$\frac{\partial^2 \mathrm{E}(W)}{\partial E \partial \beta} = \frac{\partial[\Delta \mathrm{E}(\widehat{W}) - c\widehat{I}(0)]}{\partial \beta} \frac{\partial \widehat{I}(0)}{\partial E} + (\Delta \mathrm{E}(\widehat{W}) - c\widehat{I}(0)) \frac{\partial^2 \widehat{I}(0)}{\partial E \partial \beta} + \widehat{I}(0) w' \frac{\partial \widehat{a}}{\partial E}. \tag{27}$$

From the definition of β_0, the last term in the derivative equals

$$\widehat{I}(0) w' \frac{\partial \widehat{a}}{\partial E} = -[\Delta E(\widehat{W}) - c\widehat{I}(0)] \frac{\partial \widehat{I}(0)}{\partial E} / \beta.$$

Moreover,

$$\frac{\partial \widehat{I}(0)}{\partial E} = -\frac{\beta \overline{F}}{c} \text{ and } \frac{\partial^2 \widehat{I}(0)}{\partial E \partial \beta} = -\frac{\overline{F}}{c}.$$

Substituting the last two expressions into (27), the last two terms of (27) cancel out, yielding

$$\frac{\partial^2 \mathrm{E}(W)}{\partial E \partial \beta} = \frac{\partial[\Delta \mathrm{E}(\widehat{W}) - c\widehat{I}(0)]}{\partial \beta} \frac{\partial \widehat{I}(0)}{\partial E} = (\widehat{W} - \overline{W}) \frac{\partial \widehat{I}(0)}{\partial E} > 0.$$

Hence, we have shown that

$$\left.\frac{dE^*}{d\beta}\right|_{\beta_0} > 0,$$

that is, at β_0 the optimal enforcement is always increasing in β. Therefore, there cannot be multiple values of β such that the optimal enforcement is zero as an internal solution. Summarizing, the optimal policy program implies an unique interior solution with $E^* = 0$ at $\beta = \beta_0$, positive levels of enforcement for $\beta > \beta_0$, and a corner solution with $E^* = 0$ for $\beta < \beta_0$. ■

Proof of Lemma 10. The first threshold β_0^c is defined by:

$$\beta_0^c(E=0, \underline{F}=F_{\min,}\overline{F} \geqslant F_{\min}+\underline{B}) : -[\Delta \mathrm{E}(\widehat{W}^c) - c\widehat{I}^c]\frac{\partial \widehat{I}^c}{\partial E} = \widehat{I}^c \beta w' \frac{\partial \underline{\widehat{a}}^c}{\partial E}.$$

Borrowing from the analysis of the benchmark case, we know that if $\left.\frac{\partial^2 E(W^c)}{\partial E \partial \beta}\right|_{\beta=\beta_0^c} > 0$, then the optimal enforcement E^* is zero for $\beta \in [0, \beta_0^c]$ and positive for $\beta > \beta_0^c$. Hence, β_0^c is unique. Moreover, notice that at β_0^c the marginal social value of initiative is positive, i.e. $\Delta \mathrm{E}(\widehat{W}^c) - c\widehat{I}^c > 0$.

The second threshold $\underline{\beta}_0^c$ is defined by:

$$\underline{\beta}_0^c(E=E^*>0, \underline{F}=F_{\max}-\underline{B}, \overline{F}=F_{\max}) : \Delta \mathrm{E}(\widehat{W}^c) - c\widehat{I}^c = 0.$$

From the definition of $\underline{\beta}_0^c$ we know that at $\beta = \underline{\beta}_0^c$ the first term in (19) is zero, the second is positive and the third is negative. Since $g'(E) > 0$ for $E > 0$ by assumption, we conclude that $E^* > 0$ at $\beta = \underline{\beta}_0^c$. Then, it must be that $\beta_0^c < \underline{\beta}_0^c$. ■

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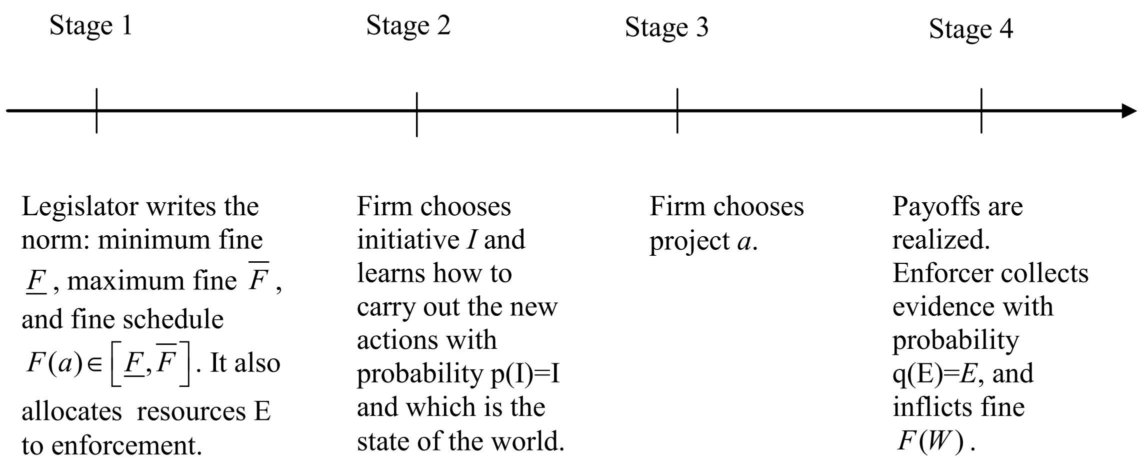

Figure 1: Time line

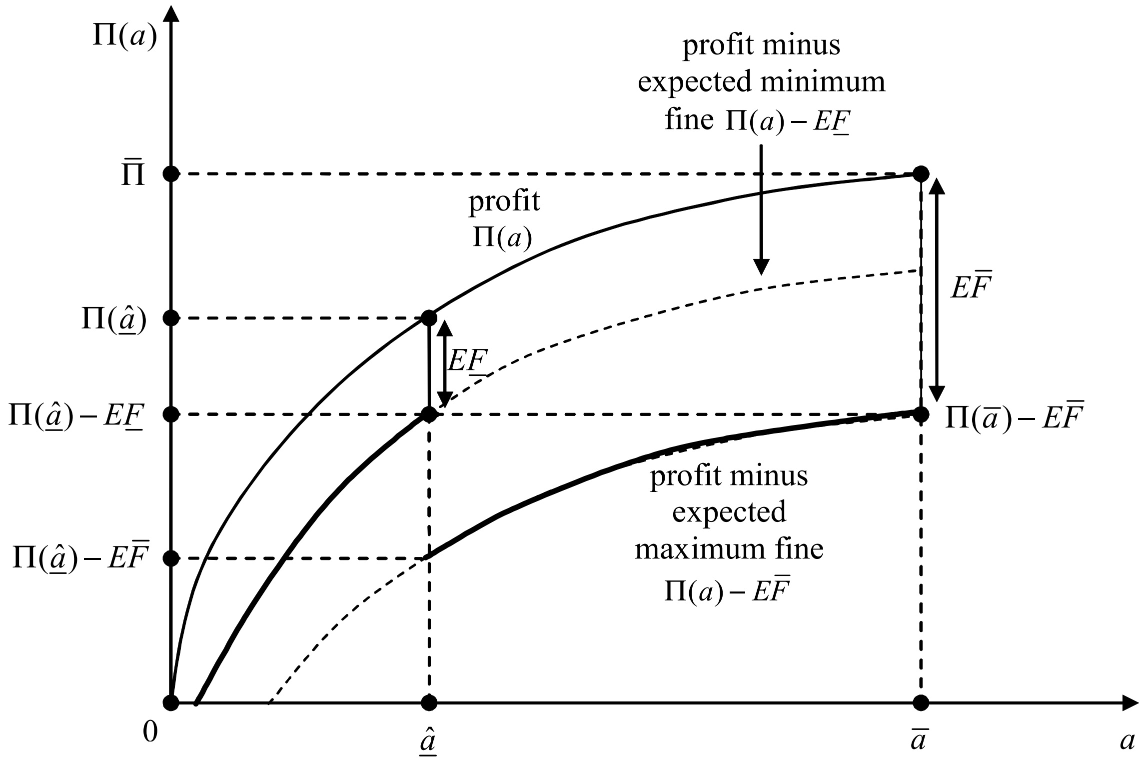

Figure 2: Actions, profits and fines

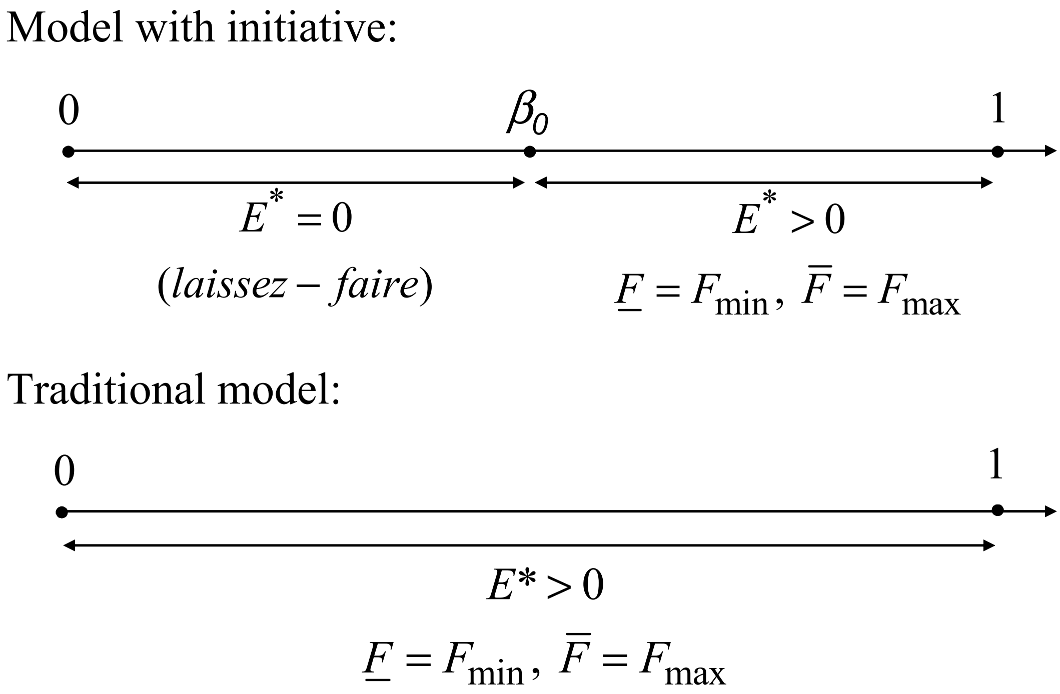

Figure 3: Optimal policy and initiative

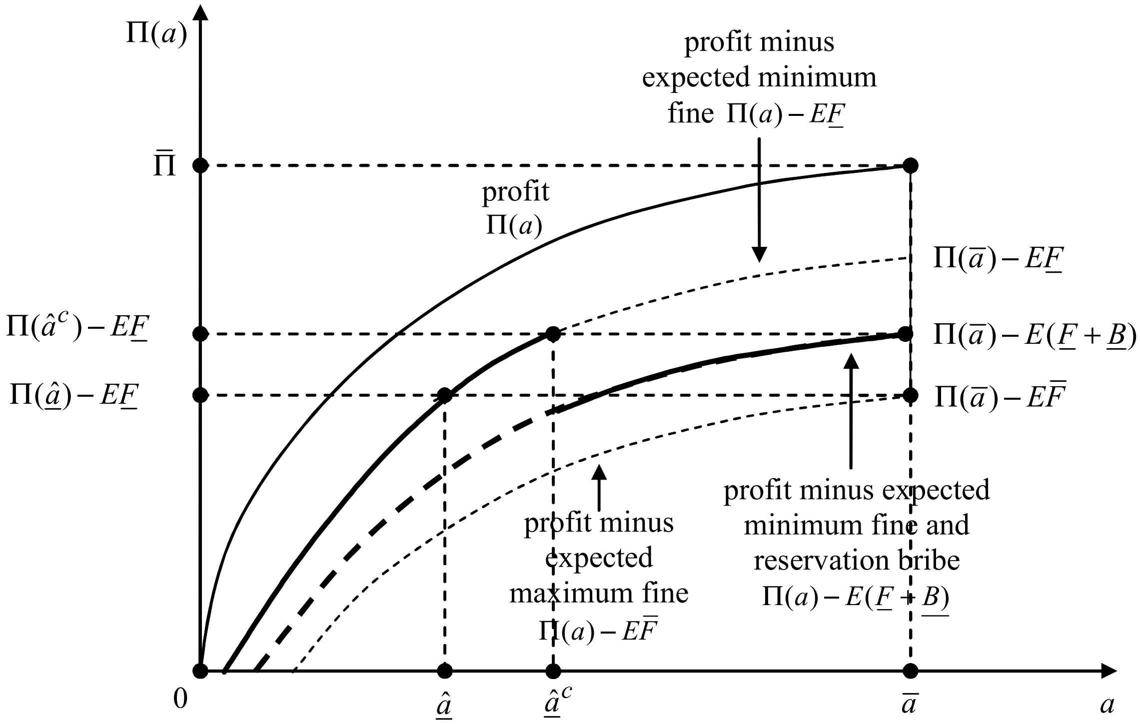

Figure 4: Actions, profits and fines with corrupt officials

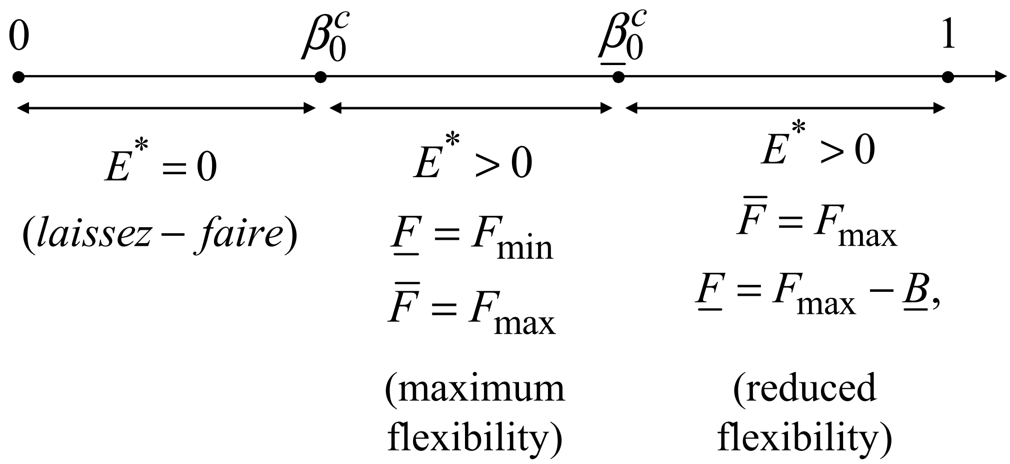

Figure 5: Optimal policy with corrupt officials