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Self-Reporting, Investigation, and Evidentiary Standards

Heiko Gerlach *University of Queensland*

Abstract

Self-reporting schemes have become a substantial part of law enforcement. This paper analyzes the optimal use of such schemes when the authority cannot commit to an ex post investigation effort. I show that this leads to a negative relationship between self-reporting incentives and investigation effort. Three main conclusions arise. First, violators self-report with a probability of 1 if and only if full amnesty is offered. Second, self-reporting schemes are not efficient when the level of harm of the act is high. Finally, authorities can increase the incentives to self-report when they convict without hard evidence. However, a hard-evidence standard provides more deterrence and is weakly welfare superior.

1. Introduction

In the last 2 decades, there has been a significant increase in the use of self-reporting schemes by government agencies and private organizations. Self-reporting schemes encourage individuals and corporations to report harmful behavior to an enforcement authority in exchange for a reduced sanction. The U.S. Environmental Protection Agency's (EPA's) self-disclosure policy provides for a 100 percent reduction in punitive fines when firms promptly disclose and correct self-discovered violations.[1] In the Antitrust Division, the U.S. Department of Justice (DOJ) introduced a new corporate leniency program in 1993, awarding automatic and complete amnesty to the first cartel member that self-reports before a cartel investigation has started. The program triggered an unprecedented number of reported and prosecuted cartels, which led the European Union and

[1] Reporting firms remain liable for fines related to the economic benefit from their violation. See Pfaff and Sanchirico (2004) for more details and an empirical evaluation of this policy.

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over 50 jurisdictions worldwide to adopt similar programs.[2] To enforce the U.S. Foreign Corrupt Practices Act (FCPA), the DOJ and the Securities and Exchange Commission have announced more generous fine reductions for voluntary disclosure of corruption-related activities.[3] In 2012, the U.S. Internal Revenue Service opened its third Offshore Voluntary Disclosure Program (after previous programs in 2009 and 2011), which offers a fine reduction of approximately 50 percent for taxpayers who report their previously undisclosed foreign accounts and assets. The Federal Aviation Authority initiated in 2008 the Air Traffic Safety Action Program as a voluntary, nonpunitive self-reporting program to encourage air traffic employees to report safety violations.

In two important papers, Kaplow and Shavell (1994) and Malik (1993) analyze the optimal design of self-reporting programs and argue that such schemes are a powerful enforcement tool. The argument is as follows. A violator has an incentive to self-report a harmful act if the authority proposes a reduced sanction that equals (or is slightly less than) the expected value of not reporting, that is, the stipulated sanction times the probability of apprehension and prosecution. This policy ensures that individuals who commit the act self-report in equilibrium, whereas the authority audits (investigates) nonoffenders with a positive probability. Thus, for a given audit probability, self-reporting permits the authority to save on costly auditing, while the individual's expected return from the act and deterrence are the same as without self-reporting. It follows that the use of self-reporting always strictly increases welfare.[4] The crux of this argument is that the enforcement authority is able to commit beforehand to an ex post investigation effort. This assumption is essential since the optimal enforcement effort is not time consistent. Ex ante, the optimal investigation effort is the one that induces an offender to self-report. However, when all offenders self-report, the authority faces, ex post, individuals who knowingly have not committed the crime. Hence, the authority is best off not investigating at all and reallocating scarce enforcement resources to other tasks. In this paper, I relax this commitment assumption and show that with time-consistent enforcement effort the authority faces a trade-off between inducing self-reporting and maintaining deterrence, which significantly limits the scope for the efficient use of self-reporting programs.

Consider the model of Kaplow and Shavell (1994) and suppose that the authority is unable to commit ex ante to an investigation effort and decides on an investigation effort after the individual's choice not to self-report. In the absence of a report, the authority does not know whether she is facing an individual who

[2] Miller (2009) provides some empirical support that the introduction of the program increased the Department of Justice's cartel detection capabilities. See Spagnolo (2008) for a comprehensive discussion of different leniency programs.

[3] In a recent case, Pfizer received a 34 percent reduction off the bottom of the fine range for U.S. Foreign Corrupt Practices Act violations recommended in the sentencing guidelines (see U.S. Department of Justice 2012).

[4] These papers also show that self-reporting programs lead to further efficiency gains when individuals are risk averse and when imprisonment is available as costly punishment.

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has committed the act and has not reported it or an individual who has not committed the act. The authority weighs the expected benefit of avoiding a type II error (acquitting a violator) against the cost of investigation. Her optimal investigation effort thus decreases both the self-reporting rate of the individual and the deterrence of the act. These negative relationships feed back into the incentives to self-report and the optimal design of the self-reporting program. First, the equilibrium self-reporting rate increases with the generosity of the self-reporting scheme. However, violators report with a probability of 1 if and only if the authority gives full amnesty. Similarly, if the program is not sufficiently lenient, there is no self-reporting at all. Second, ex ante, when the authority chooses the optimal self-reporting scheme, she faces a trade-off between inducing self-reporting and deterring the harmful act. A more lenient scheme strengthens the threat of investigation and the incentives to self-report but, at the same time, weakens deterrence. As a consequence, the use of self-reporting schemes is efficient if and only if the harm of the act is sufficiently small. When the harm of the act is significant and deterrence more valuable, the authority is best off not proposing a self-reporting scheme.

These results are derived under the assumption that the authority prosecutes only if and when the investigation is successful and yields hard evidence to convict the violator. Alternatively, the second part of this paper analyzes the effects of a lower evidentiary standard under which the authority is able to convict if—after an inconclusive investigation—the expected cost of conviction is lower than the expected cost of acquittal. I show that such a standard is able to strengthen the incentives to self-report. However, the hard evidence provides more investigation incentives and stronger deterrence and is weakly welfare superior.

This paper contributes to a growing literature on self-reporting and law enforcement. Following the work of Kaplow and Shavell (1994) and Malik (1993), several papers have identified further benefits of self-reporting programs. For example, self-reporting programs reduce the incentives of violators to engage in costly avoidance activities to prevent apprehension (Innes 2001). When violators have heterogeneous apprehension probabilities, self-reporting schemes are able to provide more targeted deterrence to different types of violators (Innes 2000). Self-reporting and self-policing also increase the frequency of ex post cleanup and/or remediation, as self-reporting firms always clean up whereas nonreporting firms remediate only when they are caught (Innes 1999a, 1999b). A similar argument is made in the context of compliance activities in Livernois and McKenna (1999).

A related, recent strand of literature analyzes self-reporting when there is a group of wrongdoers, such as firms in a price-fixing cartel or members of organized crime. Two additional features emerge with respect to law enforcement in this context.[5] The governance of the group has to ensure cooperation by all

[5] See Choi and Gerlach (forthcoming) for a discussion of the economic effects of leniency programs and a current summary of the growing experimental literature on self-reporting programs in antitrust.

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members, and self-reporting might exert negative externalities among group members and lead to prisoner's dilemmas. These issues are explored in the framework of generic law enforcement by Buccirossi and Spagnolo (2006) and in the context of cartel formation by Motta and Polo (2003), Spagnolo (2004), Aubert, Rey, and Kovacic (2006), and Harrington (2008). In all of these papers, with single or multiple wrongdoers, either the authority is able to commit to an investigation effort ex ante or the prosecution probability is exogenous.

By contrast, issues arising from a lack of commitment have been studied extensively in the literature on costly auditing. For instance, the tax audit literature studies optimal policies to induce individuals to truthfully report their income. One approach assumes that the authority is able to commit to a tax scheme and an audit schedule ex ante (Reinganum and Wilde 1985; Border and Sobel 1987; Mookherjee and Png 1989). Such a commitment enables the authority to directly impose the optimal policy, and the audit probability declines with reported income to prevent high-income taxpayers from underreporting too much. The alternative approach assumes that the authority can commit to a tax scheme but not to audit probabilities (Reinganum and Wilde 1986; Graetz, Reinganum, and Wilde 1986; Melumad and Mookherjee 1989; Chatterjee, Morton, and Mukherji 2008). In this case, the taxpayers' equilibrium reporting strategy has to adjust to provide the authority with incentives to implement a decreasing audit schedule. Hence, the equilibrium amount of underreporting has to decrease with the true income of taxpayers. In a related study, Khalil (1997) introduces audits without commitment in a standard principal-agent problem with adverse selection. In the optimal contract, the principal increases the output of the low-cost type to raise his stake in an audit and strengthen his incentives to audit ex post. A similar argument is made in Khalil and Parigi (1998), in which a lender increases the loan size to mitigate the lack of commitment at the ex post audit stage. The present paper shares the feature that, without commitment, incentives for investigation have to arise endogenously in equilibrium. The structure of the problem and the mechanism are, however, very different. One key difference is that the self-reporting literature considers not only an adverse-selection problem (with respect to the individual's benefits) but also moral hazard (with respect to whether the individual commits the socially harmful act). Thus, the authority is concerned not only with the individual's reporting strategy but also with the policy effects on ex ante deterrence. In particular, this paper shows that in the absence of commitment, the authority faces a negative relationship between self-reporting incentives and deterrence.

The paper proceeds as follows. Section 2 describes the model under the two alternative evidentiary standards. Section 3 briefly derives the optimal self-reporting program with commitment. Section 4 analyzes the equilibrium and optimal policy when the authority is unable to commit to the investigation effort ex ante. Section 5 compares the approaches and discusses the role of commitment and conditions under which commitment is more or less likely in practice.

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Section 6 considers self-reporting with a weaker evidentiary standard, while Section 7 concludes. All formal proofs are in the Appendix.

2. The Model

A risk-neutral individual chooses to commit ($c = 1$) or not to commit ($c = 0$) an act that causes a social harm ($h > 0$). The associated (potential) private benefit b is private information and distributed according to a continuous density function $f(b)$ and a cumulative distribution function $F(b)$. These distributions are common knowledge.[6]

The authority does not observe whether the act has been committed by the individual. To either convict ($d = 1$) or acquit ($d = 0$) the individual, she has two instruments, a self-reporting program and procedural investigation. The self-reporting scheme specifies that if the individual admits to the harmful act ($r = 1$), he is convicted but receives a reduced sanction $R \geq 0$. If the individual does not self-report ($r = 0$) and is subsequently convicted, he pays the full, stipulated sanction of $S \geq R$. A self-report is verifiable by the authority, as violators always produce a credible report, whereas innocent individuals never do. For the analysis, it will be useful to let $0 \leq \rho \leq 1$ denote the probability with which a violator self-reports the act. The parameters (R, S) of the self-reporting program are chosen by the authority at the beginning of the game. The maximum sanction $\bar{S}$ is exogenously determined by a wealth constraint or the availability of rewards and punishments for the individual.

In the absence of a self-report, the authority opens an investigation before making a judgment. In the course of an investigation, the authority detects the true state of the world $c \in \{0, 1\}$ with a probability of e. With the remaining probability of $1 - e$, the authority continues to be uninformed.[7] The cost of an investigation with success rate e is $C(e)$, with $C(0) = 0$, $C'(e) \geq 0$, and $C''(e) \geq 0$. Two alternative timings are considered with respect to the authority's choice of investigation effort. As a benchmark, Section 3 considers the case in which the authority can commit to an investigation effort at the beginning of the game. The remainder of the paper considers situations in which the authority is unable to commit and chooses her effort ex post.

The payoff of the authority is as follows. The authority values a correct acquittal or conviction at a normalized payoff of 0. The cost of committing an error of type I, that is, convicting an innocent individual, is $E_1 > 0$. This includes the cost of the sanction of the individual, loss of income, stigma, or loss to society from a miscarriage of justice. Similarly, the cost of committing an error of type II, that is, acquitting a guilty individual, is $E_2 > 0$. This includes any potential

[6] The setup follows the standard model of probabilistic law enforcement; see Polinsky and Shavell (2000) and Garoupa (1997) for surveys.

[7] This structure of costly information collection follows the model of Dewatripont and Tirole (1999).

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Table 1
Payoff Matrix

	$d = 0$	$d = 1$
$c = 0$	0	$-E_1$
$c = 1$	$-E_2$	0

future harm of leaving the act unpunished.[8] The payoff matrix as a function of the state of the world and the decision is shown as Table 1.

The authority is risk neutral and maximizes ex ante expected total welfare, that is, the sum of the individual's net surplus plus the authority's payoff minus the cost of investigation. The following parameter restrictions are imposed to ensure an interior solution for the investigation effort:

$$C'(0) < E_i < C'(1) \qquad \forall i \in \{1, 2\}.$$

If an investigation remains inconclusive, the authority's judgment depends on the evidentiary standard in place. In the first part of the paper, the authority uses a hard-evidence standard. Under this standard, the authority convicts if and only if the investigation is successful and the authority can infer with a probability of 1 that the individual has committed the act. Conversely, if the investigation is inconclusive, the individual is acquitted. In Section 6, I consider the effects of a weaker evidence standard. The authority convicts the individual if the expected cost of conviction is lower than the expected cost of acquittal. This means that she always convicts after a successful investigation and she may convict when the investigation effort was not conclusive but the probability of facing a violator is high.

Figure 1 summarizes the timing of the game when the authority (A) is unable to commit to her investigation effort. First, she chooses the parameters of the self-reporting program (R, S). Then, nature draws the individual's (I's) benefit b and he chooses whether to commit the act. The individual self-reports the act with a probability of ρ, in which case he incurs a reduced sanction R. If there is no self-report, the authority chooses an investigation intensity of e and then makes a judgment. If convicted, the individual pays the full sanction S.

Although the analysis is framed within the standard law enforcement model, this setup readily applies to some of the examples discussed above. For instance, the authority could be an environmental agency with incomplete information about the cost of compliance of firms where the harmful act is to disrupt compliance. In a tax context, the violation could be to illegally transfer assets overseas when the tax authority has incomplete information about an individual's cost of doing so. Similarly, this framework could encompass employers monitoring harmful activities of employees within an organization or an antitrust authority prosecuting anticompetitive practices of firms.

[8] See Andreoni (1991) for a similar payoff structure in a different context.

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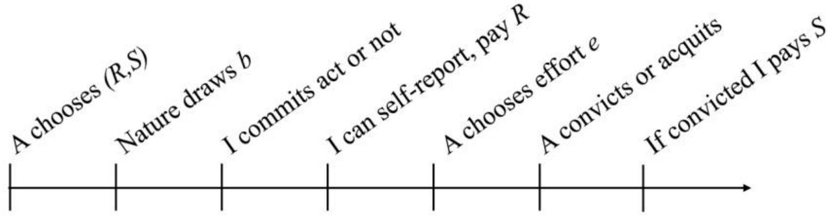

Figure 1. Timeline

3. Self-Reporting Programs with Commitment

As a benchmark, suppose that the authority can commit to her investigation effort at the beginning of the game and she adopts the hard-evidence standard; that is, she can convict only when an investigation is successful. Here the setup differs from Kaplow and Shavell (1994) in only two aspects. First, the authority incurs a cost when making type I or II errors. This ensures that, in the absence of commitment, the authority has an ex post incentive to investigate in order to avoid convicting an innocent individual or acquitting a violator. As seen below, these costs do not alter the qualitative results of Kaplow and Shavell (1994) as, in equilibrium, all violators self-report and there are no errors in judgment. Naturally, as E_1 and E_2 go to 0, this assumption coincides with Kaplow and Shavell (1994). The second difference is that instead of a linear effort cost, a more general function $C(e)$ is assumed.

With ex ante commitment, the authority chooses a policy scheme (R, S, e). The individual learns his benefit and decides whether to commit the act. If an individual self-reports, the authority is certain to face a violator and convicts the individual. In the absence of a self-report, the authority starts an investigation with a probability of e. A violator chooses to self-report (not to self-report) if the reduced fine R is strictly lower (higher) than his expected sanction eS. The probability of self-reporting is thus governed by[9]

$$\rho \begin{cases} = 1 & \text{if } R < eS, \\ \in [0,\ 1] & \text{if } R = eS, \\ = 0 & \text{if } R > eS. \end{cases} \tag{1}$$

An individual is investigated and potentially sanctioned independent of the benefit he obtains from the act. Therefore, in equilibrium, there exists a marginal individual with $B \geq 0$ who is indifferent between committing or not, while all individuals with $b \geq B$ commit the harmful act. Thus, the threshold value for the marginal violator, or the level of deterrence, is given by

[9] The notation $\rho \in [0, 1]$ means that the violator is indifferent to any reporting probability between 0 and 1.

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$$B = \min\{R,\ eS\}. \tag{2}$$

The ex ante welfare net of the cost of investigation and the cost of committing type II errors is given by

$$\begin{aligned} W_1(e,\ B,\ \rho) = \int_B^\infty (b-h)f(b)db - [1-F(B)](1-\rho)(1-e)E_2 \\ - \{[1-F(B)](1-\rho) + F(B)\}C(e). \end{aligned} \tag{3}$$

The first term is the expected net benefit, private gain minus social harm, when the individual commits the act. The second term is the expected loss when the individual commits the act, does not self-report, and is not convicted by the authority. The last term is the expected cost of investigating nonreporting violators or innocent individuals.

The authority maximizes ex ante welfare subject to equations (1) and (2). Inducing self-reporting with values such that $R < eS$ is not optimal, as the same outcome could be achieved with less investigation effort. Setting $R > eS$ implies that there is no self-reporting and is equivalent to $R = eS$ and $\rho = 0$. Thus, suppose $R = eS = B$ and consider ex ante welfare. Increasing the self-reporting probability ρ always raises welfare independent of the level of investigation effort or deterrence. Self-reporting reduces the probability of making type II errors, and it saves the cost of investigation for self-reporting individuals. Hence, it is optimal to induce self-reporting with a probability of 1. Given that all individuals self-report, the optimal stipulated sanction, S, is maximal, and the investigation effort can be used to optimally adjust ex ante deterrence. The optimal effort satisfies $dW_1/de = 0$ for $\rho = 1$, or

$$h - e\bar{S} = C(e) + \frac{F(e\bar{S})C'(e)}{\bar{S}f(e\bar{S})}, \tag{4}$$

which equates the marginal gain from avoiding net harm and the cost of investigating the marginal and the inframarginal innocent individuals. Thus, the commitment benchmark can be summarized as follows.

Proposition 1. If the authority can commit to an investigation effort ex ante, she induces self-reporting from a violator with a probability of 1. The use of self-reporting programs is always socially efficient.

In the presence of effort commitment, self-reporting programs are a powerful enforcement instrument. The policy parameters can be chosen to induce self-reporting from violators, while the investigation effort can be used to fine-tune the deterrence of the act. The use of a self-reporting scheme is always optimal independent of the parameter values of the model such as the harm of the act or the cost of errors in judgment.

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4. Self-Reporting Programs without Commitment

For the remainder of the paper, I assume that the authority is unable to commit to her investigation effort. First, I derive the equilibrium outcome for a given self-reporting scheme (R, S). Then I characterize the authority's optimal self-reporting scheme.

4.1. Equilibrium Analysis

Without ex ante commitment, the game follows the timeline in Figure 1. The authority introduces a self-reporting policy scheme (R, S). The individual learns his benefit, and all types $b \geq B$ commit the act. If an individual self-reports, the authority is certain to face a violator and convicts the individual. In the absence of a self-report, the authority decides how much investigation effort to exert. The incentive to investigate depends on how likely it is that she is able to convict a violator and avoid a type II enforcement error. The authority faces either an innocent individual or a violator who has not turned himself in. Her posterior belief γ that the individual is guilty is thus defined as

$$\gamma = \frac{\Pr\{r = 0|b \geq B\}}{\Pr\{r = 0|b \geq B\} + \Pr\{b < B\}}. \tag{5}$$

The optimal investigation effort e solves $\min_e (1 - e)\gamma E_2 + C(e)$ and minimizes the expected loss from exerting effort and making type II errors. The first-order condition for optimal effort is

$$\frac{[1 - F(B)](1 - \rho)E_2}{[1 - F(B)](1 - \rho) + F(B)} = C'(e). \tag{6}$$

Increasing effort reduces the probability of acquitting a violator. The expected marginal gain (or avoided loss) from this is the posterior belief of facing a nonreporting violator γ times the cost of making an error of type II. In an optimum, the marginal gain equates the marginal cost of exerting effort. Since the latter is increasing in e, the optimal effort increases in the posterior belief γ. This leads to the following relationship between investigation effort and deterrence and self-reporting. First, ceteris paribus, the authority's belief of facing a violator decreases in the self-reporting rate ρ. When the violator never self-reports, the belief is at its highest level of $\gamma = 1 - F(B)$, whereas for $\rho = 1$ the authority's belief is 0. Hence, the more that violators self-report, the lower the optimal investigation effort. Second, for a given self-reporting rate, an increase in deterrence, that is, a higher B, leads to a lower posterior belief. This implies that the authority investigates less when there is more ex ante deterrence.

A violator anticipates the optimal effort of the authority if he is not revealing, and self-reporting follows condition (1). An individual commits the act if his private benefit b exceeds the expected sanction. Thus, the threshold value for the marginal violator is given by equation (2). Hence, for a given policy (R, S), the equilibrium outcome (e^*, B^*, ρ^*) is determined by equations (1), (2), and (6).

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First, consider the case in which the violator's reduced penalty R is strictly less than the expected sanction eS when he is not self-reporting. This condition requires that the authority exert a strictly positive amount of effort and that violators always self-report. These two actions, however, are not compatible. If violators self-report with a probability of 1, then—following condition (6)—the authority ascribes the absence of a self-report to the fact that the individual is not guilty and does not exert investigation effort. Hence, this condition cannot hold in an equilibrium. Next, consider situations with $R > eS$ such that violators never self-report. Deterrence is determined by the marginal, nonreporting violator at $B^* = e^*S$. The optimal investigation effort follows from condition (6) for $\rho = 0$, where $e^* = \bar{e}$ and $\bar{e}$ is implicitly defined by

$$[1 - F(\bar{e}S)]E_2 = C'(\bar{e}).$$

Since the investigation effort is decreasing in ρ, the investigation effort $\bar{e}$ is the maximum investigation intensity for a given sanction S. In this equilibrium, both ex ante deterrence and the optimal investigation effort are independent of R. Conversely, an increase in the stipulated sanction S deters more individuals and lowers the optimal investigation effort. This equilibrium exists if and only if the authority's policy is not sufficiently generous relative to the maximum investigation effort, that is, if $R > R' \equiv \bar{e}S$, where R' denotes the cutoff value.

Finally, suppose that $R = eS$. In this case, a violator is indifferent and self-reports with a probability of $\rho \in [0, 1]$. This requires the optimal investigation effort to be equal to the ratio of the reduced sanction over the full sanction, $e^* = R/S$. Accordingly, the marginal individual is at $B^* = R$. To sustain this equilibrium, the optimal self-reporting probability has to adjust and equate the marginal gain and cost of effort in equation (6). This yields the equilibrium self-reporting rate

$$\rho^* = 1 - \frac{C'(R/S)F(R)}{[E_2 - C'(R/S)][1 - F(R)]}. \tag{7}$$

In order to verify under which condition this equilibrium exists, consider the effect of the policy parameters (R, S) on the equilibrium self-reporting rate.

Figure 2 illustrates an increase in the reduced penalty from R_0 to R_1. Raising R increases deterrence and reduces the authority's posterior belief that she faces a violator. This shifts down the marginal gain of effort in equation (6). At the same time, a higher value of R increases the investigation effort e^*, which leads to a higher marginal cost. Both effects imply that a higher value of R (that is, a less lenient policy) strictly reduces equilibrium self-reporting. Moreover, the self-reporting probability is nonnegative if and only if $R \leq R'$. At exactly this threshold, the self-reporting probability is 0, and the equilibrium coincides with the one characterized for $R > eS$. For higher values of R, this equilibrium fails to exist. By contrast, since ρ^* is strictly decreasing in R and $\rho^*(R = 0) = 1$, it holds that a violator self-reports with a probability of 1 if and only if the authority gives full amnesty.

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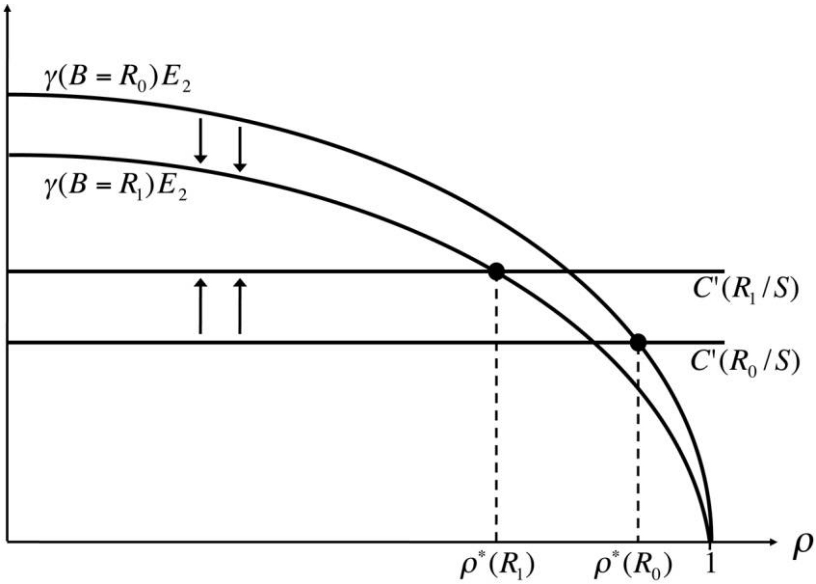

Figure 2. Effect of an increase from R_0 to R_1 on the equilibrium self-reporting rate

Further note that the second policy parameter S affects only the equilibrium investigation effort. A higher value of S reduces the investigation effort and the marginal cost of effort. Thus, self-reporting is strictly increasing in the stipulated sanction.

Lemma 1. For a given policy scheme (R, S), two equilibrium regimes arise:
(i) If the policy is sufficiently lenient ($R \leq R'$), the equilibrium self-reporting rate is given by equation (7) and the investigation effort is R/S. The self-reporting probability strictly decreases in R and increases in S.
(ii) Otherwise, violators never self-report and the investigation effort is $\bar{e}$.

The effectiveness of the self-reporting program hinges on the amount of amnesty the authority gives. If the scheme is not sufficiently lenient, self-reporting never occurs, and the authority has to rely on her investigation efforts. If the fine reduction is sufficiently generous, the self-reporting rate increases in the amount of leniency, while the optimal investigation effort decreases. However, at the same time, more leniency induces more individuals to commit the act. This introduces a trade-off between ex ante deterrence and ex post self-reporting, which is crucial to the choice of the optimal self-reporting program in Section 4.2.

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4.2. The Optimal Self-Reporting Program

The authority chooses a self-reporting scheme (R, S) to maximize ex ante welfare $W_1(e, B, \rho)$ as defined in equation (3). Each policy parameter pair induces an equilibrium outcome from one of the two regimes in lemma 1. Let $W_1^*(R, S)$ denote the ex ante welfare with the equilibrium values (e^*, B^*, ρ^*). Formally, the authority maximizes $W_1^*(R, S)$ subject to $0 \le R \le S$ and $0 \le S \le \bar{S}$. Note that we can focus on the indirect effect of R and S on welfare via the self-reporting rate ρ^* and the deterrence level B^*. It follows from an envelope theorem argument that the policy parameters do not affect welfare through the optimal investigation effort. The reason for this is that the direct effect of e on welfare is conditional on the authority not receiving a self-report and, thus, identical to its effect on the authority's objective at the interim stage.[10]

The authority has two policy options. Either she offers a sufficiently lenient self-reporting scheme $R \le R'(S)$ to induce a strictly positive self-reporting rate and the equilibrium in lemma 1.i, or she refrains from using self-reports and relies on her investigation efforts as in the equilibrium in lemma 1.ii. Next, I will briefly describe the local maximizer for each regime and then give the globally optimal policy. First, consider policy parameters that induce self-reporting. An interior solution, $R^* \in [0, R')$, must satisfy

$$\begin{aligned}\frac{dW_1^*}{dR} = {} & [h - R^* + (1 - \rho^*)(1 - e^*)E_2 - \rho^* C(e^*)]f(R^*) \\ & + [C(e^*) + (1 - e^*)E_2][1 - F(R^*)]\frac{\partial \rho^*}{\partial R} = 0. \end{aligned} \tag{8}$$

The degree of amnesty for self-reporting affects marginal deterrence and the self-reporting rate of inframarginal violators. Increasing R raises the deterrence threshold $B^* = R$. The net welfare effect of this increase is given in square brackets in the first line of equation (8). Deterring the marginal individual prevents social harm h and private benefit from the act equal to R^*, lowers the authority's probability of making type II errors, and reduces potential cost savings from self-reporting. At the same time, increasing R reduces the probability of self-reporting and thus affects the social welfare from the inframarginal individuals who commit the act. A lower self-reporting rate increases the expected cost of investigations and the probability of making type II errors. Hence, the effect through the inframarginal violators is strictly negative, which mandates strong leniency and an interior solution. However, this may be mitigated by the effect of amnesty on deterrence. Deterrence is more valuable, the greater the social harm of the act. From equation (8) it follows that if the value of h is sufficiently high, then the positive deterrence effect outweighs the gains from

[10] The effect of e on ex ante welfare is 0 in equilibrium since $dW_1/de = [1 - F(B^*)](1 - \rho^*)E_2 - \{1 - \rho^*[1 - F(B^*)]\}C'(e^*) = 0$ is identical to equilibrium condition (6). Hence, the indirect effect of (R, S) via the optimal investigation effort can be ignored.

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self-reporting. In particular, there must exist a threshold value h' such that for greater social harm the slope is positive for all $R \leq R'$ and the local maximizer is the corner solution. By contrast, if the social harm is sufficiently small, then full amnesty is the local maximizer. To see this, note that as R approaches 0, the self-reporting probability goes to 1 and the investigation effort goes to zero. In the limit, the positive effect of deterrence is solely to prevent harm h, whereas there is strictly positive gain from marginally reducing R to increase self-reporting from inframarginal violators. Thus, if h is sufficiently small, the slope in equation (8) is always negative. From this argument also follows that the threshold value h' above which there is a local corner solution, $R^* = R'$, has to be strictly positive. To conclude the characterization of this local maximum, note that the optimal stipulated sanction is always maximal since

$$\frac{\partial W_1^*}{\partial S} = [1 - F(R)][(1 - e^*)E_2 + C(e^*)]\frac{\partial \rho^*}{\partial S} > 0. \tag{9}$$

The stipulated sanction S does not affect deterrence, but it increases the probability of self-reporting. This, in turn, saves enforcement cost by reducing type II errors and by lowering the frequency of investigations.

Next, consider policy parameters $R > R'(S)$ such that the equilibrium in point ii of lemma 1 results. In this equilibrium, a violator does not self-report and the reduced sanction R has no impact on welfare. The first-order condition for an interior solution, $S^* < \bar{S}$, is

$$\frac{\partial W_1^*}{\partial S} = [h - e^*S^* + (1 - e^*)E_2]f(e^*S^*)\left(e^* + S^*\frac{\partial e^*}{\partial S^*}\right) = 0, \tag{10}$$

whereas $S^* = \bar{S}$ if $\partial W_1^*/\partial S \geq 0$ for all $S \leq \bar{S}$. The sanction S affects only the position of the marginal violator, $B = eS$. A higher value of S increases this threshold by the last term in equation (10). The effect of more deterrence on welfare is given by the term in square brackets, which sums the net welfare impact of the marginal violator, $h - e^*S^*$, and the gain from a reduction in the probability of making errors of type II. If the harm h is sufficiently great, then increasing the stipulated sanction always increases welfare and $S^* = \bar{S}$. By contrast, for lower values of h, the optimal sanction in this local maximum is less than maximal.[11]

It remains to compare the two local maximizers and derive the globally optimal policy. I show in the Appendix that if an interior local maximum with $R^* < R'$ exists, then it is always the global maximizer. Otherwise, the authority's optimal

[11] Note that in an interior solution it holds that $B^* = e^*S^* > h$. In other words, the authority is overdeterring the act in order to reduce the expected cost of making type II errors. For more details, see the proof of proposition 2 in the Appendix.

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policy is not to induce self-reporting and impose a maximum sanction on convicted violators.[12]

Proposition 2. If the authority is unable to commit to her investigation effort, the optimal policy can be described as follows:

(i) The authority uses self-reporting by violators if and only if the harm of the act is sufficiently small ($h < h'$). For more harmful acts, the authority uses only procedural investigation.

(ii) The stipulated sanction is always maximal.

In the absence of commitment, self-reporting is part of the optimal law enforcement policy mix if and only if the level of external harm of the act is sufficiently small. In order to induce self-reporting in the equilibrium of lemma 1.i, the authority needs to provide a generous policy scheme with a sufficient wedge between reduced and stipulated penalties. However, this comes at the cost of weakening the investigation effort and deterrence. Since deterrence is most valuable when the level of external harm is high, it is exactly for those values that the authority optimally implements the equilibrium of lemma 1.ii and refrains from the use of self-reporting in her enforcement strategy. Proposition 2 thus suggests a two-pronged approach in the design of self-reporting programs. The disclosure of minor regulatory breaches should be encouraged by offering (partial) amnesty from fines, whereas major violations of the law should be exempt from such schemes in order to provide investigation incentives and deterrence.

5. Self-Reporting and the Value of Commitment

The results in Section 4 are in marked contrast with those of the commitment case in Section 3 and the work by Kaplow and Shavell (1994) and Malik (1993). When the authority is able to commit to an ex post investigation effort, she is able to choose her effort (and deterrence, since $B = eS$) and the level of self-reporting independently. For any level of investigation effort, the authority is best off if she induces full self-reporting with the parameters of her policy scheme ($R = eS$). Given that all violators self-report, the authority then chooses the optimal amount of effort (and deterrence). Hence, the use of self-reporting is always beneficial, and the authority is required to investigate only the pool of individuals who have not committed the act. By contrast, when the authority is unable to commit, investigation effort (and deterrence) and self-reporting are negatively related. Inducing self-reporting comes at the cost of reducing deterrence in order to strengthen the threat of ex post investigation. Hence, when the level of external harm of the act is great, ex ante deterrence is more valuable

[12] While, for certain parameter values, a less than maximal sanction might be part of the local maximum without self-reporting, such a local maximizer is always dominated, for those parameter values, by the local maximizer of the regime with self-reporting.

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than ex post self-reporting, and the authority prefers not to offer a self-reporting scheme for violators.

It is nevertheless clear that the authority would always benefit from commitment, as its lack imposes an additional constraint on her maximization problem. In fact, the benefits of commitment can be decomposed by comparing the optimal solutions in Sections 3 and 4 for the same parameter values. At the optimal no-commitment effort level, welfare is raised—as discussed in Section 3—by increasing the self-reporting rate to the commitment equilibrium level, that is, to $\rho = 1$. Furthermore, with full self-reporting, welfare is maximized at the effort level given in equation (4). Thus, the move from the no-commitment to the commitment effort level further improves ex ante welfare.

These benefits raise the question as to how the authority could sustain commitment to the optimal investigation effort. Several mechanisms have been discussed in the literature.[13] The two most likely options in this context are reputational concerns via repeated interaction and budget investment. Many enforcement situations are based on repeated interactions between an authority and individuals. Suppose in a given period the authority announces the optimal full commitment effort and all violators behave as in the equilibrium discussed in Section 3. If, at the end of the period, the authority deviates and does not investigate, individuals and the authority revert to the no-commitment equilibrium from the next period onward. Using such a strategy, the authority would trade off the benefit from deviating (and saving investigation costs) with the cost of losing commitment in the future. A major problem with this strategy is that the optimal policy involves random investigations of innocent individuals, which makes it hard for individuals to monitor the authority's adherence to her announced investigation effort.[14] While the authority could possibly provide aggregate information on her investigation efforts, such a communication policy would face a similar credibility problem. However, without effective monitoring, the repeated-game strategy is not sustainable or at least is only partially sustainable. Hence, a necessary condition for sustaining commitment via reputation is a high level of transparency of the investigation process. This is more likely to be the case in situations in which the authority is supervising a small, stable, and nonanonymous set of individuals over time, like a regional environmental agency with a small number of big firms or a small department within an organization. By contrast, in some of the other examples, like the antitrust

[13] Outsourcing to a third party, as discussed in Melumad and Mookherjee (1989) and Picard (1996), or delegation (Mookherjee and Png 1989) imply high transaction costs, and moral hazard and commitment are limited, as there is the possibility of renegotiation. At least theoretically, the authority could also post a bond, which she would forfeit if she were not to implement the announced investigation policy.

[14] There is another, more subtle theoretical issue with this mechanism, as the authority's repeated-game strategy is in itself not renegotiation proof in the sense of Farrell and Maskin (1989). After deviating in one period, the authority could renegotiate and intend to reintroduce the full commitment strategy. In other words, conceptually, the commitment problem might simply be pushed back from the static to the repeated framework.

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leniency program, the FCPA, or tax amnesties, commitment seems to be much harder to sustain.[15] A second possible commitment device for the authority in this context is to invest ex ante in her budget in order to reduce the cost of ex post investigation. A lower marginal cost of investigation would increase the incentives to exert effort and make self-reporting programs more beneficial. However, from the comparative statics of my analysis, as long as the marginal cost is bounded away from 0, the qualitative nature of the analysis without commitment prevails. That is, self-reporting programs are not efficient when the harm of the act is sufficiently high.

6. Optimal Evidence Standard and Self-Reporting

The analysis in Section 4 shows that, in the absence of commitment, the authority faces a high cost of inducing violators to self-report. A pertinent question in this context is whether the authority would be better off by lowering the evidence standard for convictions in order to increase the threat of prosecution for violators. In this section, I investigate the effects of a weaker evidence standard on individuals' self-reporting and solve for the optimal policy scheme. Then I compare the results with those in Section 4 and derive the overall optimal evidence standard.

6.1. Equilibrium Analysis

Suppose that the authority adopts a weaker evidence standard such that she is able to convict the individual when the investigation is successful and when the investigation is inconclusive but the expected cost of a conviction is lower than the expected cost of an acquittal. This change in the evidentiary standard affects the last stage of the self-reporting game. Consider the case in which the individual does not self-report and the authority's investigation efforts do not provide hard evidence. Now the authority can either convict or acquit on the basis of her belief γ that the individual has committed the act. The authority prefers to convict if the expected loss of convicting an innocent individual, $(1 - \gamma)E_1$, is less than the expected loss of acquitting a violator, γE_2. The authority is indifferent if $\gamma = \hat{\gamma}$, where

$$\hat{\gamma} \equiv \frac{E_1}{E_1 + E_2}$$

is the critical belief level. For higher values of γ, the authority prefers to convict, and for lower values she acquits the individual. The threshold value is higher the more important the cost of type I errors is relative to type II errors. Let β

[15] For example, when the U.S. Internal Revenue Service (IRS) launched its 2011 Offshore Voluntary Disclosure Initiative, IRS commissioner Doug Shulman said, "This new disclosure initiative is the last, best chance for people to get back into the system" (U.S. Internal Revenue Service 2011). On January 9, 2012, the IRS announced another tax evasion amnesty scheme, the 2012 Voluntary Disclosure Program.

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denote the probability of conviction without hard evidence; thus,

$$\beta \begin{cases} = 0 & \text{if } \gamma < \hat{\gamma}, \\ \in [0,\ 1] & \text{if } \gamma = \hat{\gamma}, \\ = 1 & \text{otherwise.} \end{cases} \tag{11}$$

In the absence of a self-report, the authority updates her belief γ according to equation (5) before exerting investigation effort. With a probability of e, she discovers the true state of the world and makes a correct verdict. With the remaining probability, she does not receive any additional information and convicts with a probability of β. Ex ante, the authority chooses the investigation effort to minimize the cost of effort and ex post judgment errors, that is,

$$\min_{e} \gamma(1 - e)(1 - \beta)E_2 + (1 - \gamma)(1 - e)\beta E_1 + C(e).$$

The first-order condition for the optimal effort level, e^{**}, satisfies

$$(1 - \gamma)\beta E_1 + \gamma(1 - \beta)E_2 = C'(e^{**}). \tag{12}$$

The optimal investigation effort equates the expected marginal gain from avoiding type I and type II errors and the marginal cost. Given the optimal conviction rule from expression (11), the marginal gain is nonmonotonic in the posterior belief γ. For $\gamma < \hat{\gamma}$, the authority never convicts after an unsuccessful investigation and, ex ante, the authority exerts effort to minimize type II errors. Thus, the marginal gain and the incentive to exert effort increase with the authority's belief that she faces a violator. By contrast, if the belief is beyond the critical threshold, the expected cost of acquitting is high, and the authority always convicts after an unsuccessful investigation. Hence, ex ante, the authority minimizes type I errors and exerts more effort the more likely it is that she is facing an innocent individual, that is, the lower the value of γ. Consequently, the incentive to exert effort is strongest at the critical level, $\gamma = \hat{\gamma}$. At this threshold, the expected costs of type I and type II errors are equal, and the conviction probability β is irrelevant in the first-order condition. Evaluating condition (12) at the critical value $\hat{\gamma}$ yields the implicit definition of the maximum effort level of the authority $\hat{e}$ given this evidence standard,

$$\hat{\gamma}E_2 = C'(\hat{e}).$$

Next consider the decision to self-report. A violator can be convicted in two ways, by hard evidence or by a verdict based on suspicion. Thus, a violator prefers (not) to self-report if the reduced sanction is less (more) than the expected cost of facing investigation and possible conviction by the authority. He is indifferent if and only if

$$R = [e + (1 - e)\beta]S. \tag{13}$$

At the same time, an individual commits the act if his private benefit b minus the expected sanction exceeds the expected cost of conviction despite being innocent,

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$$b - \min\{R,\ [e + (1 - e)\beta]S\} \geq -(1 - e)\beta S.$$

Note that while raising the conviction probability β increases self-reporting incentives, it might not affect deterrence. Clearly, the possibility of a violator being convicted without hard evidence increases deterrence. However, at the same time, the individual who chooses not to commit the act faces the risk of being convicted because of a type I error. When a violator has no strict incentive to self-report, these effects cancel each other out, and deterrence does not depend on the conviction probability. The threshold value for the marginal violator is

$$B = \min\{R - (1 - e)\beta S,\ eS\}. \tag{14}$$

I am now in a position to sketch the equilibrium when the authority is able to convict without hard evidence.[16] Let $(e^{**}, B^{**}, \rho^{**}, \beta^{**})$ denote the equilibrium outcome for a given self-reporting policy (R, S). To simplify the exposition, I restrict attention to the following condition:

$$1 - F(\bar{e}\bar{S}) \geq \hat{\gamma}. \tag{15}$$

When expression (15) does not hold, the authority never convicts after unsuccessful investigations for any feasible policy scheme. The focus is thus on parameter values such that convictions without hard evidence might indeed be optimal for the authority. This is the case when the maximum stipulated penalty is relatively low compared with the cost of judgment errors.

First, consider an equilibrium in which the posterior belief of facing a violator is small, $\gamma < \hat{\gamma}$, and the authority does not convict when the investigation is unsuccessful. This corresponds to the analysis in Section 4.1, where this evidence standard was imposed exogenously. As shown above, when the policy scheme is sufficiently lenient, violators have an incentive to self-report. Thus, in the absence of a self-report, the authority's posterior belief of facing a violator is low, and it is not optimal to convict without hard evidence. As R increases, there is less self-reporting, and the equilibrium belief γ increases as long as $R \leq R'$. For higher values, there is no self-reporting, and the belief is constant at a level of $1 - F(\bar{e}S)$. This has two implications for the existence of this equilibrium regime. First, if and only if expression (15) is satisfied, then the belief can reach the critical level for convictions without hard evidence, that is, $\hat{\gamma}$. Second, if this condition holds, then there must exist a threshold $R'' < R'$ such that γ is strictly less than $\hat{\gamma}$ if and only if $R < R''$. For these values, there are no convictions without hard evidence, and the equilibrium follows lemma 1.i.

Next, consider the equilibrium in which the authority convicts with a strictly positive probability after an unsuccessful investigation. It is clear that in such an equilibrium the authority's belief cannot be strictly above the critical threshold $\hat{\gamma}$. If this would be the case, then the authority would always convict without hard evidence, and a violator would strictly prefer to self-report. This, however, is not compatible with a posterior belief strictly below $\hat{\gamma}$. Hence, the equilibrium

[16] The formal proof for lemma 2 is in the Appendix.

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belief has to be exactly at the critical level $\gamma = \hat{\gamma}$ such that the authority is indifferent between conviction and acquittal. The optimal investigation effort then follows from equation (12), and the authority exerts the maximum effort level, $e^{**} = \hat{e}$. Furthermore, the authority adjusts the threat of convictions without hard evidence in order to maintain the self-reporting incentives by satisfying equation (13), that is,

$$\beta^{**} = \frac{R - \hat{e}S}{(1 - \hat{e})S}. \tag{16}$$

Ceteris paribus, as R increases and self-reporting becomes less attractive, the probability of conviction without hard evidence has to rise in order to preserve the incentive to self-report. As R approaches S, the optimal conviction probability goes to 1. By contrast, there is a strictly positive probability of conviction if and only if the self-reporting scheme is not sufficiently lenient, that is, $R > R'' = \hat{e}S$. Finally, the self-reporting rate has to be consistent with a posterior belief at the critical level $\hat{\gamma}$ in order to provide an incentive to convict without hard evidence. The optimal self-reporting rate thus follows from the definition of γ in equation (5), the optimal deterrence of $B^{**} = \hat{e}S$ from equation (14), and $\gamma = \hat{\gamma}$. This yields

$$\rho^{**} = \frac{1 - F(\hat{e}S) - \hat{\gamma}}{(1 - \hat{\gamma})\left[1 - F(\hat{e}S)\right]}. \tag{17}$$

Since deterrence increases with S, the optimal self-reporting rate has to decrease with S to maintain the same posterior belief. This equilibrium self-reporting probability is strictly positive as long as condition (15) is satisfied. We can thus summarize the equilibrium outcomes for a given self-reporting policy (R, S) as follows.

Lemma 2. Suppose that condition (15) holds. Two equilibrium regimes arise:

(i) If the policy is sufficiently lenient ($R \leq R''$), the authority does not convict without hard evidence and the equilibrium outcome from lemma 1.i obtains.

(ii) Otherwise, the equilibrium conviction follows equation (16), self-reporting is given by equation (17), and the investigation effort is $\hat{e}$.

The differences between the equilibrium states with and without hard-evidence convictions are discussed below. Three observations are noteworthy at this point. First, even if the authority chooses a standard that allows her to convict without hard evidence, it might still be optimal in equilibrium not to do so and rely on hard evidence only. This occurs if the policy scheme is lenient and induces a high self-reporting rate and a low probability of committing type II errors. Second, with this weaker evidentiary standard, self-reporting always occurs with a strictly positive probability for any feasible policy parameter pair (R, S). This is due to the fact that an increase in R can be offset by raising the conviction probability in order to satisfy the self-reporting constraint in equation (13). Third, and related, if $R > R''$, then the equilibrium self-reporting rate, the in-

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vestigation effort, and deterrence are independent of the policy parameter R. The conviction probability β^{**} increases in R but—as demonstrated in equation (14)—does not affect deterrence of the act. At the same time, the investigation effort is capped at $\hat{e}$ such that the equilibrium belief is at its critical level $\hat{\gamma}$. This implies that both deterrence and the self-reporting rate are invariant in R for any $R \geq R''$.

6.2. *Optimal Self-Reporting Program*

Consider the optimal self-reporting program when the authority is able to convict without hard evidence. Ex ante welfare for a given vector (e, B, ρ, β) is

$$W_2(e, B, \rho, \beta) = \int_B^\infty (b - h)f(b)db - (1 - F(B))(1 - \rho)(1 - e)(1 - \beta)E_2 \\ - F(B)(1 - e)\beta E_1 - [(1 - F(B))(1 - \rho) + F(B)]C(e). \tag{18}$$

The first term is the welfare contribution from marginal deterrence. The second and third terms are the expected cost of acquitting a violator and convicting an innocent individual, respectively. The last term is the expected cost of investigating nonreporters. Ceteris paribus, there are two differences for total welfare with a hard-evidence standard from equation (3). Convictions without hard evidence reduce the probability of making type II errors by a factor of $1 - \beta$ in the second term of equation (18). At the same time, they introduce the possibility of making type I errors in the third term. Conversely, if there is no conviction without hard evidence, $\beta = 0$, then ex ante welfare is equal to W_1.

Let $W_2^*(R, S)$ denote the ex ante welfare with the equilibrium values $(e^{**}, B^{**}, \rho^{**}, \beta^{**})$. The authority maximizes this ex ante welfare with respect to (R, S). The policy parameters induce one of the two equilibrium regimes described in lemma 2. For values $R \in [0, R''(S)]$, the authority convicts only with hard evidence, and the same equilibrium and welfare obtain as in lemma 1.i. From the analysis in Section 4.2, it follows that the local maximizer is at $S^{**} = \bar{S}$, whereas the optimal R is determined by condition (8). As the optimal reduced penalty strictly increases in the harm h, there must exist a cutoff value for the harm, denoted h'', below which an interior solution $R^{**} < R''(\bar{S})$ exists, whereas for higher values there is a corner solution. Moreover, since the upper bound of the regime is lower under the weaker evidence standard, $R''(S) < R'(S)$, the harm cutoff value for interior solutions must be lower, too; that is, $h'' < h'$. This observation is useful when comparing the evidence standards.[17]

The authority compares the above local maximizer with the one for $R \in (R''(S), S]$, where there is a strictly positive probability that the authority convicts after an unsuccessful investigation. In this equilibrium, the reduced penalty R affects the equilibrium (and ex ante welfare) only through the conviction prob-

[17] Put differently, there exist intermediate values of the harm such that the local maximizer with the hard-evidence standard is interior, $R \in (R''(S), R'(\bar{S}))$, whereas the local maximizer with the lower evidence standard is a corner solution, $R^{**} = R''(\bar{S})$.

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ability β^{**}. A less lenient program (a higher R) increases the probability of conviction without hard evidence. This, in turn, raises the expected cost of making type I errors and reduces the expected cost of making errors of type II. However, in equilibrium the authority is ex post indifferent between convicting and acquitting, and these two effects of β on welfare cancel each other out.[18] Hence, welfare is independent of the level of R in this regime. By contrast, the stipulated sanction S enters welfare through the deterrence level and the self-reporting probability. Taking the derivative of $W_2^*(R, S)$ with respect to S, substituting the equilibrium values, and rearranging yields

$$\frac{\partial W_2^*(R,\ S)}{\partial S} = \hat{e}f(\hat{e}S)\left[h - \hat{e}S - E_1(1-\hat{e}) - \frac{E_1 + E_2}{E_2}C(\hat{e})\right]. \tag{19}$$

The first term in square brackets, $h - \hat{e}S$, is the direct effect from an increase in deterrence. The second term is the effect of S on the cost from judgment errors.[19] The last term is the effect of the sanction on the cost of investigation.[20] As in the analysis of condition (10) in Section 4.2, the local maximizer is a corner solution $S^{**} = \bar{S}$ when the harm is sufficiently high such that the marginal benefit of deterrence always dominates the marginal cost of increasing the sanction. Otherwise, the local maximizer is interior, $S^{**} < \bar{S}$. The next proposition compares the local maximizer of the two regimes and gives the globally optimal policy $(R^{**},\ S^{**})$ with this evidentiary standard.

Proposition 3. Suppose the authority can convict without hard evidence and condition (15) holds. If the harm of the act is sufficiently small ($h < h''$), the authority offers a more lenient policy and chooses not to convict without hard evidence. Otherwise, for more harmful acts, she chooses a less lenient policy and convicts without hard evidence. The optimal stipulated sanction is always maximal.

The authority's optimal enforcement policy includes convictions without hard evidence if and only if the harm of the act is sufficiently large. In these situations, ex ante deterrence is relatively more important than ex post enforcement. This favors a less lenient policy with respect to self-reporting in order to strengthen investigation effort and deterrence. The optimal stipulated sanction is maximal, as convictions without hard evidence are only globally optimal for high values of h, and, thus, a corner solution $S^{**} = \bar{S}$ obtains in this equilibrium regime.

[18] From the definition of ρ^{**} in equation (17), it follows that $1 - \rho^{**} = E_1F(\hat{e}S)/[E_2(1 - F(\hat{e}S))]$ and $\partial W_2/\partial\beta = (1-\hat{e})\{-F(\hat{e}S)E_1 + [1 - F(\hat{e}S)](1-\rho^{**})E_2\} = 0$, and total welfare is invariant in R for $R \in (R'', S]$.

[19] In equilibrium, the expected costs of making errors of type I and type II are the same. Hence, the combined cost of error in judgment is $F(eS)(1-e)E_1$, which increases with the number of innocent individuals.

[20] A higher value of S shifts the marginal individual from not committing (and being investigated with a probability of 1) to the pool of violators who are investigated only if they are not self-reporting. Thus, the cost of investigation increases in deterrence and S.

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6.3. Optimal Evidentiary Standard

Now compare the two evidentiary standards in terms of equilibrium behavior and welfare under their respective, optimal self-reporting policies. First, consider the equilibrium outcomes.

Figure 3 depicts equilibrium deterrence and self-reporting as a function of the reduced sanction R. The dashed lines represent the values under the hard-evidence standard; the bold lines denote the values when the authority can convict without hard evidence.

Different cases arise as a function of the harm of the act. If the harm is less than h'', then the optimal policy is $R^* = R^{**} \leq R''(\bar{S})$ and the induced behavior is the same under both standards. When the authority uses the hard-evidence standard and the harm is intermediate, the optimal reduced sanction is between $R''(\bar{S})$ and $R'(\bar{S})$. This reduces equilibrium self-reporting but increases investigation effort and deterrence. When the harm exceeds h', then the optimal policy implies $R^* \geq R'(\bar{S})$ such that there is no self-reporting and deterrence is capped at $\bar{e}\bar{S}$. By contrast, when the authority can convict without hard evidence and the harm is greater than h'', the optimal scheme implies $R^{**} \geq R''(\bar{S})$. Instead of increasing the investigation effort, the authority introduces convictions without hard evidence. While convictions without hard evidence maintain the self-reporting incentives, they do not increase deterrence, which is capped at a lower level. Hence, if the harm is larger than h'', convictions without hard evidence increase self-reporting but reduce the incentives to investigate and deterrence relative to their levels under the hard-evidence standard.

Now compare ex ante welfare for $h > h''$. Two observations allow me to make a revealed-preference argument. First, if the authority can convict without hard evidence, welfare is invariant in R for $R \in [R''(\bar{S}), \bar{S}]$. Second, welfare at $R = R''(\bar{S})$ is the same under both standards. Hence, since $R^* > R''(\bar{S})$ for $h > h''$, it holds that

$$W_1^*(R^*, S^*) = W_1^*(R^*, \bar{S}) > W_1^*(R''(\bar{S}), \bar{S}) = W_2^*(R''(\bar{S}), \bar{S}) = W_2^*(R^{**}, S^{**});$$

that is, welfare is strictly higher with the hard-evidence standard. The comparative advantage of the hard-evidence standard is that it provides a self-reporting scheme with more leverage to deter individuals. When the harm of the act is large, an authority can increase deterrence and welfare by making the self-reporting scheme less attractive. This adjustment is not available when the authority is able to use convictions without hard evidence. Raising the reduced penalty only increases the frequency of convictions without hard evidence, which has no effect on deterrence and ex ante expected welfare. This is summarized as follows.

Proposition 4. Suppose condition (15) holds, and compare the two evidentiary standards. If the harm of the act is small ($h \leq h''$), both standards yield the same outcome and welfare. For more harmful acts, the hard-evidence standard is strictly welfare superior.

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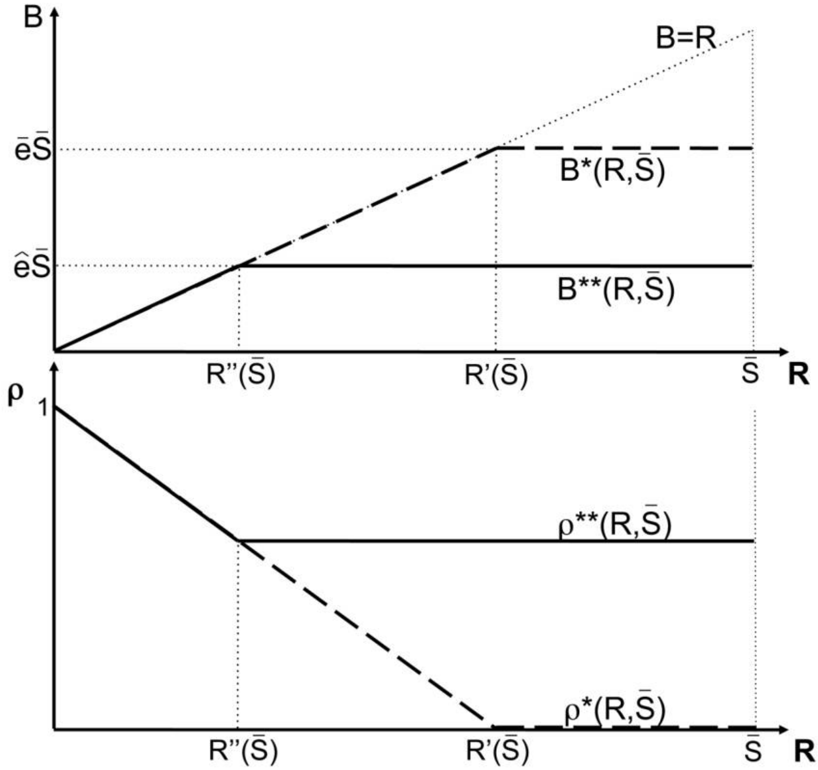

Figure 3. Equilibrium values with different evidentiary standards

This result has clear-cut implications for the globally optimal enforcement strategy with respect to self-reporting schemes and evidence standards. The optimal choice of the evidence standard does not affect the condition under which it is efficient to use self-reporting schemes. If the harm of the act is small ($h \leq h'$), the authority optimally uses a self-reporting scheme and the hard-evidence standard. For more harmful acts, it is efficient not to offer a self-reporting program and to enforce with deterrence and procedural investigation using a hard-evidence standard.

7. Conclusions

Self-reporting programs have become a substantial part of law enforcement in many circumstances from environmental protection to antitrust violations and internal compliance within organizations. This paper analyzes self-reporting and its optimal use in situations in which the authority is unable to commit to

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an ex post investigation effort. Two main conclusions arise. First, in contrast to the case with commitment, it is not always efficient for an authority to use self-reporting programs. A lack of commitment introduces a negative relationship between the self-reporting rate and both the investigation effort and deterrence. To induce individuals to self-report, the authority is required to weaken deterrence in order to provide a threat of ex post investigation and prosecution. This introduces a cost that is particularly important when deterrence is more valuable. Hence, when the harm of the act is sufficiently large, the authority is best off not to use a self-reporting scheme and to rely on deterrence and procedural investigation.

The difficulty of inducing self-reporting in the absence of commitment raises the question as to whether the authority could do better by lowering the evidentiary standard in order to strengthen the threat of prosecution. The second main result of the paper asserts that this is not the case. While a weaker evidence standard leads to more equilibrium self-reporting, it is an imperfect substitute for investigation effort, as it introduces type I errors and innocent individuals are wrongfully convicted. This has a negative, first-order effect on ex ante deterrence, which outweighs the positive effect of an increased threat of ex post conviction. As a consequence, self-reporting programs are more effective in conjunction with high evidentiary standards.

Overall, this paper provides novel insights with respect to the optimal design of self-reporting programs. However, the results also suggest a somewhat cautious approach toward the use of such schemes. The optimal design of a self-reporting program crucially depends on whether the authority is able to commit to an investigation effort ex ante. As discussed in the paper, the ability to commit is a function of the institutional details of a given regulatory situation, in particular with respect to the transparency of the process and the number and composition of individuals. In the absence of such commitment, self-reporting schemes should be implemented only for minor legal violations. Finally, the results are derived in the framework of Kaplow and Shavell (1994). It is clear that relaxing the full-commitment assumption might also have important consequences for the analysis of self-reporting programs in the context of remediation, self-policing, avoidance activities, or targeted enforcement strategies. Exploration of these matters is left for future research.

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Appendix

Proofs

Proof of Lemma 1

Suppose that $0 < \rho^* < 1$. Then (B^*, ρ^*, e^*) follows from equations (1), (2), and (6). This equilibrium holds as long as $\rho^* \geq 0$ or

$$C'(R/S) \leq E_2[1 - F(R)]. \tag{A1}$$

The left-hand side is strictly increasing, and the right-hand side is strictly decreasing in R. At $R = 0$, this condition always holds since $C'(0) < E_2$. At $R = S$, because $C'(1) > E_2$, the left-hand side is strictly larger than E_2. It follows that there exists a unique R' that satisfies the above condition as an equality and above which the equilibrium in lemma 1.i fails to exist. From expression (A1) and the definition of $\bar{e}$ in the text, it follows that $R' = \bar{e}S$.

Suppose that $\rho^* = 0$. From equation (6), it follows that $e^* = \bar{e}$. From equation (1), it has to hold that $R > e^*S$, and it follows from equation (2) that $B^* = e^*S$. This equilibrium holds for any $R > R' = \bar{e}S$.

Suppose that $\rho^* = 1$. Then, $R < e^*S$ and $\gamma = 0/F(B)$. If $C'(0) > 0$, then there is no solution to equation (6). If $C'(0) = 0$, then $e^* = 0$, which contradicts $R < e^*S$.

The comparative statics follow from

$$\frac{\partial \rho^*}{\partial S} = \frac{E_2(R/S)F(r)C''(R/S)}{S[1 - F(R)][E_2 - C'(R/S)]^2} > 0,$$

$$\frac{\partial \rho^*}{\partial R} = -\frac{S[(E_2 - C'(e^*)]C'(e^*)f(R) + E_2C''(e^*)[1 - F(R)]F(R)}{S[1 - F(R)]^2[E_2 - C'(e^*)]^2} < 0,$$

and, from totally differentiating equilibrium condition (6),

$$\frac{\partial e^*}{\partial S} = -\frac{f(e^*S)e^*}{Sf(e^*S) + C''(e^*)/E_2} < 0.$$

Q.E.D.

Proof of Proposition 2

Total welfare $W_1^*(R, S)$ is a continuous, piecewise function with the two regimes defined in lemma 1. For notational convenience, I denote the welfare function and local maximizer of these regimes with an additional subscript 1 and 2, respectively. Further assume that this welfare function is piecewise concave in (R, S). To find the global maximizer, I analyze the two local maximizers and then compare. First note that the threshold value $R'(S)$ satisfies $R'(0) = 0$, $R'(\bar{S}) < \bar{S}$, and, from totally differentiating the equality of expression (A1),

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$$\frac{dR'}{dS} = \frac{RC''(R/S)}{E_2S^2f(R) + SC''(R/S)} > 0.$$

Local Maximizer $(R^*{}_1, S^*{}_1)$ *for* $R \in [0, R'(S)]$ *and* $S \in [0, \bar{S}]$. As derived in the text, $S_1^* = \bar{S}$. Simplifying equation (8) further yields

$$\begin{aligned}\frac{\partial W_{11}^*}{\partial R} &= (h - R)f(R) - \frac{E_2 f(R)}{E_2 - C'(e^*)}[C(e^*) + (1 - e^*)C'(e^*)] \\ &\quad - \frac{E_2F(R)C''(e^*)}{\bar{S}[E_2 - C'(e^*)]^2}[C(e^*) + (1 - e^*)E_2] = 0.\end{aligned} \tag{A2}$$

Next calculate the value of this derivative at $R = R'(\bar{S}) = \bar{e}\bar{S}$. At this cutoff, it holds that $C'(\bar{e}) = [1 - F(\bar{e}\bar{S})]E_2$. Substituting and rearranging yields

$$\begin{aligned}\frac{\partial W_{11}^*}{\partial R}\Big|_{R=R'(\bar{S})} &= (h - \bar{e}\bar{S} + (1 - \bar{e})E_2)f(\bar{e}\bar{S}) \\ &\quad - \frac{[(1 - \bar{e})E_2 + C(\bar{e})][E_2\bar{S}f(\bar{e}\bar{S}) + C''(\bar{e})]}{E_2\bar{S}F(\bar{e}\bar{S})}.\end{aligned}$$

This expression is negative for sufficiently small values of h, strictly increasing in h, and positive for $h \geq h'$, where

$$h' \equiv \bar{e}\bar{S} - (1 - \bar{e})E_2 + \frac{[(1 - \bar{e})E_2 + C(\bar{e})][E_2\bar{S}f(\bar{e}\bar{S}) + C''(\bar{e})]}{E_2\bar{S}f(\bar{e}\bar{S})F(\bar{e}\bar{S})}.$$

From concavity it follows that if $h < h'$, then there is an interior solution $(R_1^* = \tilde{R}_1^*, S_1^* = \bar{S})$, where $\tilde{R}_1^*$ is implicitly defined by equation (A2) and satisfies $\tilde{R}_1^* \in [0, R'(\bar{S}))$. If $h \geq h'$, then the local maximizer is $(R_1^* = R'(\bar{S}), S_1^* = \bar{S})$.

Local Maximizer (R_2^*, S_2^*) *for* $R \in [R'(S), S]$ *and* $S \in [0, \bar{S}]$. The term W_{12}^* is independent of R in this region. From equation (10) it follows that if $h < \hat{h} \equiv \bar{e}\bar{S} - (1 - \bar{e})E_2$, then $S_2^* = \tilde{S}_2^* < \bar{S}$, where $\tilde{S}_2^*$ is defined by

$$h = e^*(\tilde{S}_2^*)\tilde{S}_2^* - [1 - e^*(\tilde{S}_2^*)]E_2. \tag{A3}$$

Otherwise, if $h \geq \hat{h}$, then $S_2^* = \bar{S}$.

Global Maximizer. Note that $\hat{h} < h'$. Suppose that $h < \hat{h}$ such that $R_1^* = \tilde{R}_1^* \leq R'(\bar{S})$ and $S_2^* = \tilde{S}_2^* < \bar{S}$. From $dR'/dS > 0$ and concavity it follows that

$$W_{11}^*(R_1^*, S_1^* = \bar{S}) \geq W_{11}^*(R'(\tilde{S}_2^*), \bar{S}) > W_{11}^*(R'(\tilde{S}_2^*), \tilde{S}_2^*) = W_{12}^*(R_2^*, S_2^*),$$

and the local maximizer of regime i strictly dominates. Then suppose that $h \geq \hat{h}$ and $S_2^* = \bar{S}$. It holds that

$$W_{11}^*(R_1^*, S_1^* = \bar{S}) \geq W_{11}^*(R'(\bar{S}), \bar{S}) = W_{12}^*(R_2^*, S_2^*).$$

The first inequality is strict if and only if $h \in [\hat{h}, h')$; that is, $R_1^* = \tilde{R}_1^* \leq R'(\bar{S})$. In this case, the local maximizer of regime i strictly dominates. Otherwise, the local maximums of the two regimes are the same. The proposition follows. Q.E.D.

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Proof of Lemma 2

Suppose that $\beta^{**} = 0$. This yields the equilibrium of lemma 1 and holds as long as $\gamma \leq \hat{\gamma}$. The posterior belief γ in this equilibrium increases in R and takes its highest value, $1 - F(\bar{e}S)$, for $R \geq R'$. Define the threshold value $\hat{S}$ as $1 - F(\bar{e}\hat{S}) = \hat{\gamma}$. Thus, if $1 - F(\bar{e}S) \leq \hat{\gamma}$ or $S \geq \hat{S}$, then the equilibrium from lemma 1 exists for all values of $R \leq S$. In particular, if $R \leq R'$, then the equilibrium from part i holds; if $R > R'$, then the equilibrium from part ii exists. Now assume that $1 - F(\bar{e}S) > \hat{\gamma}$ or $S < \hat{S}$. An equilibrium with $\rho^{**} = \rho^{*} > 0$ as defined in lemma 1.i exists for values of R such that the posterior belief satisfies $\gamma = C'(R/S)/E_2 \leq \hat{\gamma}$. Denote R'' as the value that satisfies this condition with equality. Since R' is defined by $C'(R'/S)/E_2 = 1 - F(\bar{e}S)$, it holds that if $\hat{\gamma} \leq 1 - F(\bar{e}S)$ or $S \leq \hat{S}$, then $R''(S) \leq R'(S)$. This also implies that an equilibrium with $\rho = 0$ as in lemma 1.ii does not exist for $1 - F(\bar{e}S) > \hat{\gamma}$ or $S < \hat{S}$.

Suppose that $0 < \beta^{**} \leq 1$. From the argument in the text it has to hold that $\gamma = \hat{\gamma}$, and from equation (12) it follows that $\hat{\gamma} = C'(e)/E_2$ or $e^{**} = \hat{e}$. First, consider situations in which equation (13) holds and the conviction probability is given by equation (16). A nonnegative probability requires that $R \geq R'' = \hat{e}S$. From equations (14) and (5) follow $B^{**} = \hat{e}S$ and ρ^{**} in equation (17). To ensure that $\rho^{**} \geq 0$, it has to hold that $\hat{\gamma} \leq 1 - F(\hat{e}S)$. Remember the definitions of $\bar{e}$, $1 - F(\bar{e}S) = C'(\bar{e})/E_2$, and of $\hat{e}$, $\hat{\gamma} = C'(\hat{e})/E_2$. Since $1 - F(eS)$ is decreasing in e and $C'(e)/E_2$ is increasing in e, it follows that if and only if $\hat{\gamma} \leq 1 - F(\bar{e}S)$, or $S \leq \hat{S}$, then $\hat{e} \leq \bar{e}$. This implies that, when $\hat{e} \leq \bar{e}$, it holds that $\hat{\gamma} = C'(\hat{e})/E_2 \leq 1 - F(\hat{e}S)$. Hence, such an equilibrium exists if $R > R''$ and $S \leq \hat{S}$. Second, check situations in which violators have a strict incentive to self-report, $R < [e + (1 - e)\beta]S$, such that $\rho^{**} = 1$ and $\gamma = 0$. This implies that $\beta = 0$, and from equation (12) it follows that $e = 0$. This, however, does not satisfy the self-reporting constraint for any $R \geq 0$. Hence, such an equilibrium does not exist. Finally, consider situations in which violators have no incentive to self-report, $R > [e + (1 - e)\beta]S$ and $\rho^{**} = 0$. This implies that $B^{**} = \hat{e}S$ and $\gamma = 1 - F(\hat{e}S) = \hat{\gamma}$. The latter is feasible only if $S = \hat{S}$, where $\hat{e} = \bar{e}$ and $R' = R''$. Thus, at these parameter values, this case is equivalent with lemma 1.ii.

Summary. If $\hat{S} \leq S \leq \bar{S}$, then $\beta^{*} = 0$, and the equilibrium from lemma 1 holds. If $S < \hat{S}$ and $R \leq R''$, then $\beta^{*} = 0$, and the equilibrium from lemma 1.i holds. If $S < \hat{S}$ and $R > R''$, then $\beta^{*} > 0$ and the equilibrium given in lemma 2.ii holds. Finally, note that $\hat{S} \geq \bar{S}$ if and only if $1 - F(\bar{e}\bar{S}) \geq \hat{\gamma}$. This is condition (15) in the text, and lemma 2 follows. Q.E.D.

Proof of Proposition 3

Assume that $W_2^{*}(R, S)$ is a continuous, piecewise concave function with the two regimes defined in lemma 2. Let $W_{21}^{*}(R, S)$ and $W_{22}^{*}(R, S)$ denote welfare in regime i and regime ii, respectively.

Local Maximizer (R_1^{**}, S_1^{**}) *for* $R \in [0, R''(S)]$ *and* $S \in [0, \bar{S}]$. From the equilibrium analysis it follows that $W_{21}^{*}(R, S) = W_{11}^{*}(R, S)$, and from proposition 2 it

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holds that $S_1^{**} = S_1^* = \bar{S}$. It further follows from the first-order condition (A2) that the optimal R increases in h. Hence, since $R''(S) < R'(S)$, there exists a unique h'', with $0 < h'' < h'$, such that if $h < h''$, then an interior solution with $R_1^{**} = R_1^* = \tilde{R}_1^* < R''$ exists. To derive the cutoff value h'', calculate condition (A2) at $R = R''(\bar{S})$ using $e^{**} = \hat{e}$ and $C'(\hat{e}) = E_1E_2/(E_1 + E_2)$. From $\partial W_{21}^*/\partial R(R = R''(\bar{S})) = 0$ it follows that

$$h'' \equiv \hat{e}\bar{S} + (1 - \hat{e})E_1 + \frac{E_1 + E_2}{E_2}C(\hat{e}) + \frac{(E_1 + E_2)^2[(1 - \hat{e})E_2 + C(\hat{e})]F(\hat{e}\bar{S})C''(e)}{E_2^3\bar{S}}.$$

Otherwise, if $h \geq h''$, the local maximizer is $(R_1^{**} = R''(\bar{S}),\ S_1^{**} = \bar{S})$.

Local Maximizer (R_2^{**}, S_2^{**}) *for* $R \in [R''(S), S]$ *and* $S \in [0, \bar{S}]$. From the definition of ρ^{**} in equation (17), it follows that $1 - \rho^{**} = E_1F(eS)/[E_2(1 - F(eS))]$, which implies that

$$\frac{\partial W_2}{\partial \beta} = (1 - \hat{e})[-F(\hat{e}S)E_1 + (1 - F(\hat{e}S))(1 - \rho^{**})E_2] = 0.$$

Thus, total welfare is invariant in this regime. For the same reason, the indirect welfare effect of S via β is 0. Moreover, the optimal effort $\hat{e}$ is independent of S, and we get

$$\frac{\partial W}{\partial S} = (h - \hat{e}S)\hat{e}f(\hat{e}S) - (1 - \hat{e})E_2\hat{e}f(\hat{e}S) - \left[\rho^{**}\hat{e}f(\hat{e}S) - (1 - F(\hat{e}S))\frac{\partial \rho^{**}}{\partial S}\right]C(\hat{e})$$
$$+ (1 - \hat{e})(1 - \beta^{**})E_2\left[(1 - \rho^{**})\hat{e}f(\hat{e}S) + (1 - F(\hat{e}S))\frac{\partial \rho^{**}}{\partial S}\right].$$

To simplify and obtain equation (19), check that $\partial\rho^{**}/\partial S = -\hat{e}E_1f(eS)/[E_2(1 - F(eS))^2]$ and substitute in ρ^{**} and β^{**} from lemma 2.ii. Verify from equation (19) that if $h < \tilde{h} \equiv \hat{e}\bar{S} + E_1(1 - \hat{e}) + (E_1 + E_2)C(\hat{e})/E_2$, then an interior maximizer $S_2^{**} = \tilde{S}_2^{**} < \bar{S}$ exists where $\tilde{S}_2^{**}$ is defined by

$$\hat{e}\tilde{S}_2^{**} = h - E_1(1 - \hat{e}) - \frac{E_1 + E_2}{E_2}C(\hat{e}).$$

If $h \geq \tilde{h}$, then $S_2^{**} = \bar{S}$.

Global Maximizer. First, note that $\tilde{h} < h''$. Suppose that $h < \tilde{h}$ such that an interior local maximizer $S_2^{**} = \tilde{S}_2^{**}$ for regime ii exists. From concavity and the fact that W_{22}^* is independent of R, it follows that

$$W_{21}^*(R_1^{**}, \bar{S}) \geq W_{21}^*(R''(S_2^{**}), \bar{S}) > W_{21}^*(R''(S_2^{**}), S_2^{**})$$
$$= W_{22}^*(R''(S_2^{**}), S_2^{**}) = W_{22}^*(R_2^{**}, S_2^{**}),$$

and the local maximizer of regime i strictly dominates. Next consider $h \geq \tilde{h}$ such that the local maximizer of regime ii is at $S_2^{**} = \bar{S}$. Check that

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$$W_{21}^{*}(R_1^{**}, \bar{S}) \geq W_{21}^{*}(R''(\bar{S}), \bar{S}) = W_{22}^{*}(R''(\bar{S}), \bar{S}) = W_{22}^{*}(R_2^{**}, S_2^{**} = \bar{S}).$$

If $h < h''$, then the local maximizer of regime i is at $R_1^{**} < R''(\bar{S})$, and the first inequality is strict. In this case, the local maximizer of regime i strictly dominates the local maximizer of regime ii. If $h \geq h''$, then the local maximums of the two regimes are the same. The proposition follows. Q.E.D.

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