

Optimal Accomplice-Witnesses Regulation under Asymmetric Information*

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Abstract

We analyze the problem of a Legislator dealing with privately informed whistleblowers. We identify their incentives to release distorted testimonies and characterize the second-best policy limiting this behavior. The key finding is that there exists a positive externality between criminal earnings and the information rent granted to whistleblowers, which leads to partial disclosure. We also show that accomplices must fulfill minimal information requirements, that a bonus is awarded to those providing more corroborating evidence and that rewarding a self-reporting ‘boss’ increases efficiency. Moreover, we identify a set of conditions under which partial disclosure weakens, and some where it instead exacerbates.

Keywords: Accomplice-witnesses, Adverse Selection, Leniency, Organized Crime.

1 Introduction

Successful prosecution of criminal organizations often rests upon the uncorroborated testimonies of cooperating accomplices (whistleblowers). This is because the most culpable and dangerous individuals rarely do the ‘dirty job’: even if they are ultimately responsible for the crimes committed by their ‘soldiers’, these people hardly get convicted because they mainly deal through intermediaries and push their own participation up to behind-the-scenes control and guidance — see, e.g., Jeffries and Gleeson (1995).

As a result, many countries have introduced innovative legal rules (leniency programs) facilitating the use of insider information in criminal proceedings. Accomplices’ testimonies can indeed provide a richly detailed context¹ to a case, which can help making the public proceeding against a defendant compelling.

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¹For instance, that members of a criminal organization met at a particular location and that the witness was in a position to know about the types of criminal acts at issue.

However, criminals turn informants and cooperate only when the deal they are offered warrants legal and/or monetary benefits that (at least) cover the costs of remaining loyal to the organization. And this form of ‘horse-trading’ exacerbates the greater is the risk of retribution by their former partners — see, e.g., Schur (1988). Intimidation in criminal proceedings, for instance, may trigger untruthful testimonies: a danger that has repeatedly thrown serious doubts on the efficacy of these laws.²

What are the costs and benefits of leniency in criminal proceedings where accomplices own insider information that can be verified only to a limited extent? Do these people have the right incentives to disclose their private information? Is it really necessary to reward them with judicial leniency?

To address these issues, we study a model that explains why informants may profit from releasing biased testimonies, and allows to characterize the instruments that a benevolent Legislator (whose aim is to minimize crimes) can use to limit such behavior. Our main conclusion is that, under full commitment, the interplay between insider information and the risk of witness intimidation leads to a second-best policy that purposefully allows whistleblowers to hide part of their private information, but that at the same time imposes admission requirements that are more demanding than the first-best rule.

The analysis involves a hierarchical criminal organization and a Legislator. The criminal organization is formed by two mobsters that are in a principal-agent type of relationship: a boss (principal) and a fellow (agent), each with specific skills. The boss plans the crime and delegates its execution to the fellow. After the crime has been committed, some evidence about the boss’ involvement into the crime materializes. This evidence is observed only by the criminals, but neither by the prosecutors nor by the jury ruling the trial. The crime triggers an investigation and, at this stage, the agent can opt to blow the whistle by disclosing information that complements and corroborates the evidence gathered by the prosecutors and/or the police forces. The prize for cooperation entails an amnesty announced by the Legislator at the outset of the game. Moreover, the Legislator can also enforce restrictions on the program admission policy and commit to a disclosure rule mapping the agent’s (private) information into a (public) testimony.

We show that when the relationship between the Legislator and the informants is plagued by asymmetric information, there is a positive (vertical) externality between the need for granting rents to whistleblowers (in order to elicit truthful information) and the boss’ illegal earnings. The point is that better corroborating testimonies imply a higher conviction probability for the boss, whose retribution ability weakens when convicted and jailed. Hence, when the hard evidence that can be gathered against the boss is quite reliable, an accomplice might profit from hiding part of his private information. This is because pretending to face a high risk of reprisal, allows to bargain amnesties that are more lenient than what efficiency would mandate. This possibility generates an ex-post information rent for the accomplice that stifles the reservation wage he needs to be offered in order to accept the illegal deal, thus increasing the boss’ willingness to commit the

²There is much controversy concerning accomplice witnesses both on the efficiency and fairness grounds. In Germany, for instance, arguments against the use of accomplice witnesses are based on: “The principle of equal treatment and principles of proportionality and legality.... Additionally, there have been doubts expressed about the level of truthfulness in the testimony of accomplice witnesses...” (Huber, 2001). Other countries, like those of Anglo-Saxon tradition, mainly underline the necessary role played by cooperating accomplices in criminal justice, especially when a state of emergency is justified because of organized crime.

crime to the detriment of society.

This externality is the source of a marked difference between the second- and first-best policies. Under complete information the accomplice has no mimicking opportunities because his information is public. As a result, the efficient policy requires full information disclosure, it is chosen so as to make the accomplice indifferent between blowing the whistle and facing the trial, and entails no entry restrictions to the program. By contrast, to induce truthful information revelation, the second-best policy must award better deals (i.e., excessively lenient amnesties) to flipping criminals providing more corroborating information. Moreover, to minimize the implied rents, the Legislator has to *ration* the access to the program, and is forced to require accomplices not to fully disclose their private information: *partial disclosure*.

Besides its novel insights on the optimal design of leniency programs under asymmetric information, this characterization also provides a normative benchmark to understand what kind of distortions emerge when the baseline model key assumptions are relaxed. We find that the optimal policy requires full information disclosure when there is lack of commitment on the Legislator's side and when the social goal is to maximize conviction rates. In both scenarios the (constrained) optimal policy cannot improve upon the second-best allocation and features unresponsive and excessive amnesties. By contrast, we also show that the partial disclosure result survives (and it may even exacerbate) under the hypothesis of substitutability between the accomplice's testimony and the evidence that can be gathered against the boss; when retribution is tailored to the accomplice's testimony; when the benefits for cooperation are recognized only if the boss is convicted; and when a protection program is taken into account. Finally, the analysis is extended to the case where the benefit of an amnesty is also awarded to a *self-reporting* boss. In this case, we show that allowing the boss to plea guilty and cheat his fellow may enhance efficiency when the agent's information has a high corroborating value. Essentially, enabling the boss to self report reduces the set of contingencies in which the agent blows the whistle, which in turn reduces the latter's information rent. Hence, the optimal policy features a less selective admission criterion and a better disclosure rule.

The model predictions are consistent with a number of legal provisions characterizing accomplice-witnesses regulations across the world. They suggest that the benefits of these programs in terms of reduced crime may justify, at least from an efficiency point of view, the risk of biased testimonies and the recognition of pronounced legal benefits to cooperating accomplices. These insights appeal to a number of other interesting contexts, which include the optimal design of leniency programs in the fight against cartels³, po-

³With appropriate modeling changes, our approach could be used to study the role of uncorroborated testimonies on cartel formation in oligopolistic markets. A mechanism design approach like the one we propose is missing in this literature — see, e.g., Spagnolo (2008) and the literature review in Section 2.

litical⁴ and religious⁵ terrorism and corporate crimes.⁶ All these organizations typically feature hierarchal command chains and build their power on intimidation and retribution not only across their borders but also among their members, the two key features of our theoretical construct.

The rest of the paper is organized as follows. Section 2 links our contribution to the existing literature. In Section 3 we set up the benchmark model and determine first the efficient policy, and then characterize the second-best policy. Section 4 extends the benchmark model in several directions. In Section 5 we consider the case where the benefit of an amnesty is also awarded to a self-reporting boss. Section 6 concludes. All proofs are in the Appendix.

2 Related literature

Our analysis is related to the literature on *organized crime*. Traditionally, this literature has stressed welfare comparisons between monopoly and competitive supply of bads — see, e.g., Buchanan (1973) and Backhaus (1979). More recently, Jennings (1984), Polo (1995), Konrad and Skaperdas (1997, 1998) and Garoupa (2000) started to model criminal organizations as vertical structures whose heads need to discipline their fellows.⁷ But, these models have overlooked the role of accomplice-witnesses programs as a tool to generate conflict within criminal organizations, which is instead the starting point of our analysis. Koffman and Lawarree (1996) offer a first model where collusion in a hierarchy can be prevented by leniency. Buccirosi and Spagnolo (2006) show that a moderate form of leniency can have the counterproductive effect of facilitating occasional illegal transactions. Differently from us, in Buccirosi and Spagnolo (2006) criminal organizations are not modeled as vertical structures and reported evidence is not a by-product of the crime, but it is collected by criminals to be used as a threat to strengthen the sustainability of the organization itself.

Our paper is also linked to Baccara and Bar-Isaac (2008). They analyze the link between the optimal design of criminal organizations and the information flow diffused through their hierarchies, by considering both vertical and horizontal structures. We focus only on the former type of organizations, but explore

⁴Notably, insider information has been key in the fight against the Italian Red Brigades, responsible for numerous violent incidents, assassinations, and robberies during the 1970s and 1980s, and the German Baader-Meinhof, a violent terrorist group founded on Marxist ideology.

⁵For instance, in late 2010 the U.S. government requested the early release of Mohammed Babar, who was arrested in 2004 and pled guilty of providing material support and funds to al Qaeda. According to the government, he has since provided significant help to the U.S., the Canadian and the U.K. governments, in terror investigations. Because of his cooperation, the government asked for an appropriate reduction in his sentence even though federal sentencing guidelines indicate a sentence of 30 to 70 years in prison.

⁶More generally, our analysis can be also applied to study the problem of a Government that seeks to control the behavior of corporations' top management and public officials that may profit from inducing their 'employees' to infringe the law — e.g., by using technologies that are dangerous to the environment and final consumers in the case of private firms or by undertaking improper government activities in the case of public bureaucracies. For these latter types of crimes, the US *Whistleblower Protection Act* (WPA) provides statutory protections for federal employees who engage in "whistleblowing" — see, e.g., Whitaker (2007). Similarly, under the *United Nations Convention against Corruption*, States parties are called upon to take appropriate measures for the protection of witnesses against retaliation or intimidation for their testimony. Under the Convention, protection is granted to witness collaborators as well as to victims who become witnesses. Our theory suggests that similar benefits should be granted to accomplice witnesses as well.

⁷See also Fiorentini and Peltzman (1995), Kugler, Verdier and Zenou (2005) and Mansour et al. (2006).

the link between leniency programs and insider information, an issue that is not addressed in their set-up. Recently, Acconcia et al. (2009) have developed a simple model of hierarchical criminal organizations where the Legislator grants legal benefits to low-rank criminals who decide to cooperate with the justice. By using data collected for Italy, they identify the positive effect of the Italian accomplice-witness program introduced in 1991 on prosecution and argue that it also strengthened deterrence.⁸ Our analysis is motivated by this evidence and it extends the theoretical framework developed in Acconcia et al. (2009) in three main directions. First, in contrast to them, we consider a setting where the accomplice's information is non-verifiable. Second, we enlarge the Legislator's set of instruments to include, besides the amnesty rate, an information floor below which an agent's testimony is not accepted. Third, we also consider the possibility of awarding an amnesty to a self-reporting boss and show that this is sometimes necessary to fight organized crime. In this dimension, our work also relates to the 'self-reporting' literature. In Kaplow and Shavell (1994), for instance, self-reporting saves enforcement resources because individuals who report their harmful acts need not be detected, and it reduces risk because these individuals bear certain rather than uncertain sanctions. In our model, instead, the welfare enhancing effect of self-reporting stems from the hierarchical nature of criminal organizations, and it becomes more relevant the more severe is the asymmetry of information between the Legislator and the cooperating accomplices.

The idea of applying leniency to criminal organizations builds upon the *antitrust* law enforcement literature, which started with the pioneering work by Motta and Polo (2003), and studies the effects of leniency programs on cartel formation in oligopolistic markets.⁹ In this literature there are few papers that study the role of information disclosure. Feess and Walzl (2004), for instance, show that more informed (self-reporting) parties should receive more generous benefits than less informed ones, even though their main focus is not on the optimal information revelation mechanism as stressed in our analysis. The idea that, under asymmetric information, an optimal policy might require a minimum level of testimony for any leniency to be awarded also emerges in Harrington (2008) that studies optimal corporate leniency policy. In his analysis, a leniency application is accepted if and only if the government's case is sufficiently weak which means that the leniency applicant must satisfy some minimum condition on the incremental value of his testimony. Harrington (2008) is the first paper that studies how valuable the reported information must be for leniency to be awarded. However, the information reported is assumed to be hard (i.e., verifiable by third parties).

Silbye (2010), Sauvagnat (2010) and Harrington (2011) also allow for some form of private information on the probability of conviction when no firm has applied for leniency. Specifically, in Harrington (2011) each cartel member has private information on the likelihood that the authority will be able to convict them in the absence of any cooperation. Instead, Silbye (2010) assumes that the probability of conviction is common knowledge, but each firm can submit evidence that harms the other cartel members. In contrast to both these papers that characterize the equilibrium outcome of the game between the privately informed cartel members, we are more interested in the mechanism issues connected to the design of an optimal leniency

⁸Similar evidence for antitrust cases is presented in Miller (2009).

⁹Besides Motta and Polo (2003) see also Rey (2003), Spagnolo (2003), Aubert et al. (2006), Chen and Harrington (2007), and Chen and Rey (2007).

policy in criminal proceedings. Finally, differently from us, Sauvagnat (2010) studies an informed principal problem where the authority has private information about the strength of its case and decides strategically whether to open an investigation or not.¹⁰

3 The benchmark model

Players: Consider a game between a benevolent Legislator and two members of a hierarchical criminal organization — i.e., the boss (principal) and his fellow (agent). The Legislator, having forbidden welfare reducing criminal acts, designs an accomplice-witnesses program. Each member of the criminal organization owns specific skills: the boss *plans* the crime and delegates its *execution* to the fellow. The crime yields a (random) monetary return π distributed over the compact support $\Pi \equiv [0, \bar{\pi}]$ according to the cumulative distribution function (cdf) $G(\pi)$. The boss has full bargaining power and makes a take-it or leave-it offer to the fellow upon observing the crime return (π). The offer consists of a wage w to be paid after the crime is committed. If the agent refuses the offer, the game ends and both criminals enjoy their reservation utility (normalized to 0 for simplicity). Committing the crime triggers an investigation with probability α , which is standardized to 1 with no loss of insights.

Information: Once the crime is committed and the wage w is paid, some information about the boss and his involvement into the crime materializes. Both criminals, but not the Legislator, learn this information which is however the source of the hard evidence that can be gathered and used against the boss by the judicial authority. It is modeled as the realization of a random variable θ distributed over the compact support $\Theta \equiv [0, \bar{\theta}]$ according to the twice continuously differentiable and atomless cdf $F(\theta)$, with density $f(\theta)$.

Legal regimes: There are two legal regimes:

- *No leniency:* When prosecuted, the agent is sent to trial. He is convicted, and bears a sanction S_a , with probability p . The principal is convicted, and bears the sanction S_p , with probability $q(\theta)$.
- *Leniency:* In this regime the agent can decide to blow the whistle and cooperate with the justice. If so, he enjoys an amnesty $\phi(s)$ in exchange of a testimony s which, together with θ , determines the probability $Q(s, \theta)$ of convicting the boss.

The idea is that criminal cooperation naturally generates relation-specific information — i.e., information on each others’ misbehavior — that ‘whistleblowers’ can eventually (fully or partially) disclose to law enforcers to the detriment of their former partners. This feature is reflected, in our setting, through the

¹⁰The literature on *plea bargaining* also shares common features with our paper. In these models the prosecutor that is concerned with achieving the greatest possible punishment, uses plea bargaining as a means to save scarce resources by avoiding taking all defendants to trial (Landes, 1971). More recently, Kobayashi (1992) interprets plea bargaining as a device through which a prosecutor “buys information”, see also the survey by Gazal-Ayal and Riza (2009).

conviction probabilities with and without leniency — i.e., $Q(s, \theta)$ and $q(\theta)$, respectively — which depend on two key variables θ and s . In particular, θ is an exogenous measure of the potentially available evidence that can be brought at the trial against the boss, regardless of whether the fellow blows the whistle. By contrast, s is the accomplice’s testimony and represents a source of soft information (usually oral statements, see, e.g., Cassidy, 2004) that complements the available hard evidence gathered by prosecutors. Essentially, through their testimonies, accomplices provide a key to *decode* and *interpret* in the right manner the (often intricate) hard evidence brought at the trial.¹¹

Throughout we make the following assumptions on the shape of these probabilities:

- A1** $Q(s, \theta)$ and $q(\theta)$ are continuous and twice continuously differentiable. They are both increasing and (weakly) concave in θ . $Q(s, \theta)$ is single peaked with respect to s and satisfies: $Q_s(s, \theta) = 0$ for $s = \theta$, $Q(s, \theta) > Q(0, \theta) \equiv q(\theta)$ for all θ and $s > 0$.

The positive impact of θ on the conviction probabilities with an without leniency — i.e., $Q_\theta(s, \theta) > 0$ and $q_\theta(\theta) > 0$ — reflects the outcome of an (un-modelled) information gathering activity undertaken by the prosecutors and investigative forces (e.g., shadowing the agent, tapping his phone, checking his bank account etc.) that contributes to determine the trial’s final outcome by converting into hard information the potentially available evidence θ . That $Q(\cdot)$ has a maximum at $s = \theta$ simply reflects the idea that the risk of conviction for the boss is larger when the accomplice’s testimony is more congruent with the available hard evidence — i.e., when $|s - \theta|$ gets smaller.

- A2** $Q_{s\theta}(\cdot) > 0$ for all (θ, s) — i.e., increasing differences.

Increasing differences simply means that the testimony (s) and the measure of the potentially available evidence (θ) are complementary inputs in the conviction technology: more hard evidence (gathered by the investigators) has a bigger marginal effect when there is more corroborating evidence provided by the testimony (in Section 4 we relax this assumption by considering also substitutability).

The following example shows that the assumptions stated in **A1** and **A2** can be met altogether. Notice, in particular, that increasing differences in s and θ can fit in with the condition that conviction is maximized when $s = \theta$

$$Q(s, \theta) = \sigma\left(\theta - \frac{1}{2}s\right)s + \gamma\sqrt{\theta},$$

with $\sigma > 0$, $\gamma > 0$ and $q(\theta) = \gamma\sqrt{\theta}$ — i.e., $Q(0, \theta) = q(\theta)$.

Direct revelation mechanism: There is no loss of generality in invoking the Revelation Principle in this framework (see, e.g., Laffont and Martimort, 2002). Hence, we restrict attention to deterministic direct mechanisms that are piecewise continuously differentiable of class C^1 . When launching a leniency program,

¹¹The use of uncorroborated testimonies is an accepted instrument which helps convicting the heads of criminal organizations. In the U.S. federal courts defendants can be convicted solely on the basis of the uncorroborated testimony of the accomplices and also in Italy, the minimum requirements of evidence are lower in cases in which the defendant is accused of organized crime.

the Legislator commits to a policy $\mathcal{L} = \left\{ \phi(\hat{\theta}), s(\hat{\theta}) \right\}_{\hat{\theta} \in \Theta}$ specifying an amnesty $\phi(\cdot)$, with $\phi : \Theta \rightarrow \mathfrak{R}$, and a testimony $s(\cdot)$, with $s : \Theta \rightarrow \Theta$, both contingent on the agent's report $\hat{\theta}$, which is interpreted as a private signal sent by the whistleblower to the prosecutor.^{12,13} Essentially, cooperation is rewarded with a reduction $\phi(\hat{\theta})$ of the sanction S_a , but requires a public testimony $s(\hat{\theta})$ for every report $\hat{\theta}$.

Finally, in addition to the (direct) revelation mechanism, we also allow the Legislator to commit to an information floor $\underline{\theta}$: below this threshold a testimony is not accepted.¹⁴ Clearly, if $\underline{\theta} > \bar{\theta}$ the program is shut down and agents are always sent to trial.

Remark 1. The interpretation of the difference between the report $\hat{\theta}$ and the testimony s rests on the legal praxis, which usually hinges on the following rules:¹⁵ the prosecutor meets the ‘flipping criminal’ and on the basis of the elicited information (the report $\hat{\theta}$), he decides the testimony (s) to be released in trial. It is important to note that these pretrial meetings between the prosecutor/s heading the public accuse and the informant are not accessible to third parties and, for many reasons including secrecy due to safety concerns, what they discuss can be verifiable only to a limited extent by the jury or the judge/s ruling the trial as well as by the defendants’ attorneys. Hence, there seems to be a *potential* difference between the private report that the accomplice makes to the prosecutor and the public testimony that he is asked to deliver in trial.

Intimidation risk and retribution: Criminal organizations seek to punish disloyalty and, when they succeed in doing so, a constant loss $R > 0$ is inflicted to whistleblowers (in Section 4 we consider the case where this loss is contingent on the accomplice’s testimony). We assume that retribution is successful only when the boss is acquitted, which occurs with probability $1 - Q(s, \theta)$. This is with no loss of insights under the hypothesis that the retaliation ability of the boss weakens once he is convicted and jailed. Notice that, not only the boss’s ability to retaliate weakens, but also it is less in his best interest to enact retribution. Indeed, the primary reason for the boss to harm a former accomplice who turns government witness is to deter other accomplices from doing so in the future. However, if the criminal activities of the boss are curtailed due to being in jail, he attaches less value to such a reputation and thus a weakened incentive to incur a costly action to maintain that reputation.

Timing: The timing of the game is as follows:

t=0 The Legislator decides whether to launch a leniency program and accordingly commits to a policy $\wp = (\mathcal{L}, \underline{\theta})$.

¹²As explained in Cassidy (2004), the prosecutor is the public official in charge of proposing and motivating to the jury leniency for the whistleblower with whom he interacts.

¹³Since rewards are often granted in practice, we do not restrict ourselves to the case where ϕ is in $[0, 1]$.

¹⁴This rationing instrument could be modeled in a more sophisticated manner by assuming that the mechanism $\mathcal{L} = \left\{ \phi(\hat{\theta}), s(\hat{\theta}), \beta(\hat{\theta}) \right\}_{\hat{\theta} \in \Theta}$ also specifies a probability $\beta(\cdot)$ of being admitted into the program — see, .e.g., Myerson (1981). In this case the floor $\underline{\theta}$ would be such that $\underline{\theta} = \sup \{ \theta : \beta(\theta) = 0 \}$. For simplicity we assume that the Legislator can directly announce this floor.

¹⁵See, e.g., the *United Nations document on Good Practices for the Protection of Witnesses in Criminal Proceedings Involving Organized Crime* (2008) and Cassidy (2004).

t=1 Uncertainty about π resolves and the boss decides whether to commit the crime. If so, he offers the wage w to the agent. If the offer is rejected the game ends. Otherwise, once the illegal act is committed, the wage w is paid and the game proceeds to the next stage.

t=2 A realization of θ materializes. The investigation opens and, if the leniency program is in place, the agent can opt to blow the whistle.

t=3 The trial uncertainty resolves and sanctions (including the retaliation loss) are imposed.

Actions and equilibrium concept: The boss decides whether to commit the crime and makes a wage offer w to the agent. The agent can accept or reject the offer and, if prosecuted, he also decides whether to confess and what report to make. The Legislator announces a policy φ . The solution concept is Perfect Bayesian Equilibrium (PBE).

Assumptions: The analysis will be conducted under the following additional technical requirements.

A3 Decreasing inverse hazard rate — i.e.,

$$\frac{\partial}{\partial \theta} \left[\frac{1 - F(\theta)}{f(\theta)} \right] \leq 0 \quad \forall \theta \in \Theta.$$

This is a standard assumption in the screening literature. Moreover, to focus on separating equilibria it will be convenient to assume that:

A4 $Q_{s\theta\theta}(\cdot) \leq 0$ and $Q_{ss\theta}(\cdot) \geq 0$ for all s and θ .

As a *tie-breaking* condition we assume that whenever indifferent between joining the program and facing the trial, the agent blows the whistle. All players are risk neutral. Moreover, following the literature, all sanctions will be interpreted as the monetary equivalent of the imprisonment terms, fines, damages, and so forth, to which the criminals expose themselves.

Social goal: We assume that the Legislator's objective is to minimize crimes (in Section 4 we study the case of a self interested enforcer that only cares about convicting the boss). Let $C(\varphi)$ and $w(\varphi)$ denote the boss' expected sanction and the agent's break-even wage, respectively. Then committing the crime yields a non negative expected utility to the boss if and only if the return π exceeds the (total) expected costs — i.e., $\pi \geq C(\varphi) + w(\varphi) \equiv \underline{\pi}(\varphi)$. Hence, the Legislator's optimal policy φ will be chosen so as to minimize the (expected) crime rate $\Pr(\pi \geq \underline{\pi}(\varphi))$ subject to the relevant participation and incentive constraints.

3.1 First-best policy

In this section we develop the benchmark where the realization of θ is common knowledge. Let

$$u(\theta) = -(1 - \phi(\theta)) S_a - (1 - Q(s(\theta), \theta)) R,$$

be the utility of a type- θ agent who enters the program: he delivers a testimonies $s(\theta)$, enjoys an amnesty $\phi(\theta)$ and bears the retribution loss R with probability $1 - Q(s(\theta), \theta)$ — i.e., in the event that the boss is acquitted. Moreover, let $u_0 = -pS_a$ be the agent's expected utility (penalty) when facing the trial.

Clearly, in every state θ where the agent can apply to the program — i.e., if $\theta \geq \underline{\theta}$ — the Legislator chooses the amnesty rate $\phi(\theta)$ and the testimony $s(\theta)$, so as to equalize $u(\theta)$ and u_0 — i.e.,

$$(1 - \phi(\theta)) S_a + (1 - Q(s(\theta), \theta)) R = pS_a. \quad (1)$$

For any policy \wp such that (1) holds, the boss commits the crime if and only if the revenue π exceeds his expected costs — i.e., $\pi \geq C(\wp) + w(\wp) \equiv \underline{\pi}(\wp)$ — where the boss' expected sanction $C(\wp)$ is:

$$C(\wp) = S_p \int_0^{\underline{\theta}} q(\theta) dF(\theta) + S_p \int_{\underline{\theta}}^{\bar{\theta}} Q(s(\theta), \theta) dF(\theta), \quad (2)$$

and the agent's break even wage $w(\wp)$ solves the following participation constraint:

$$w(\wp) + \int_0^{\underline{\theta}} u_0 dF(\theta) + \int_{\underline{\theta}}^{\bar{\theta}} u(\theta) dF(\theta) = 0 \implies w(\wp) = pS_a \quad \forall \underline{\theta}. \quad (3)$$

Hence:

$$\underline{\pi}(\wp) \equiv pS_a + S_p \int_0^{\underline{\theta}} q(\theta) dF(\theta) + S_p \int_{\underline{\theta}}^{\bar{\theta}} Q(s(\theta), \theta) dF(\theta),$$

The Legislator's optimization program is then:

$$\max_{\wp} \Pr(\pi \leq \underline{\pi}(\wp)) \iff \max_{\underline{\theta}, s(\theta)} \left\{ \int_0^{\underline{\theta}} q(\theta) dF(\theta) + \int_{\underline{\theta}}^{\bar{\theta}} Q(s(\theta), \theta) dF(\theta) \right\}, \quad (4)$$

whose solution determines the first-best policy described below:

Proposition 1 *Assume A1. The first-best policy \wp^{fb} has the following properties:*

- (No rationing) *The whistleblower is always admitted into the program — i.e., $\underline{\theta}^{fb} = 0$.*
- (Full disclosure) *There is full information disclosure — i.e., $s^{fb}(\theta) = \theta$ for each θ .*
- (Zero-rent) *There are no rents left to the whistleblower — i.e., $u^{fb}(\theta) = u_0$ for each θ .*

Under complete information there is no reason to distort the agent’s testimony: he fully reveals his private information in court. Moreover, it will be efficient not to restrict the access to the program because the agent’s information is always productive — i.e., $Q(\theta, \theta) > q(\theta)$ for all $\theta > 0$.

3.2 Second-best policy

We now turn to analyze the case of private information. In this scenario, depending on the shape of the mechanism \mathcal{L} , in state θ the whistleblower might gain from providing an untruthful report $\hat{\theta}$ in order to enjoy a lighter sanction. These mimicking opportunities force the Legislator to distort the optimal policy for rent extraction reasons.

To characterize the incentive feasible allocations, let

$$u(\hat{\theta}, \theta) = -(1 - \phi(\hat{\theta}))S_a - (1 - Q(s(\hat{\theta}), \theta))R,$$

be the agent’s utility in θ given his report $\hat{\theta}$. An incentive feasible allocation must induce truthful information revelation by those agents that are admitted into the program and, if the floor $\underline{\theta}$ exceeds 0, it must also be such that rationed accomplices do not find it profitable to lie in order to join the program.

First, an incentive feasible policy must satisfy the following first- and second- order local conditions for truth-telling:

$$u_{\hat{\theta}}(\hat{\theta}, \theta) \Big|_{\hat{\theta}=\theta} = 0 \quad \Leftrightarrow \quad \dot{\phi}(\theta)S_a + Q_s(s(\theta), \theta) \dot{s}(\theta) R = 0 \quad \forall \theta \geq \underline{\theta}, \quad (5)$$

$$u_{\hat{\theta}\hat{\theta}}(\hat{\theta}, \theta) \Big|_{\hat{\theta}=\theta} \geq 0 \quad \Leftrightarrow \quad \dot{s}(\theta) Q_{s\theta}(s(\theta), \theta) R \geq 0 \quad \forall \theta \geq \underline{\theta}, \quad (6)$$

in addition to the participation constraint:

$$u(\theta) \geq u_0 \quad \forall \theta \geq \underline{\theta}. \quad (7)$$

These conditions ensure that (locally) the cooperating accomplice has no incentive to manipulate his information and that he prefers to join the program rather than being sent to trial.¹⁶ As standard, an envelope argument allows to rewrite the first-order incentive compatibility constraint as:

$$\dot{u}(\theta) = Q_{\theta}(s(\theta), \theta) R \quad \forall \theta \geq \underline{\theta}. \quad (8)$$

Hence, under **A1** the information rent $u(\theta)$ is increasing — i.e., $\dot{u}(\theta) > 0$. Agents with better information have an incentive to mimic downward because the higher risk of retaliation — the probability $1 - Q(s(\theta), \theta)$ is decreasing in θ — allows to request a more generous amnesty in exchange of a testimony. This induces the agent to under-report in order to enjoy lighter (expected) sanctions than it would be necessary from the

¹⁶We shall verify in the Appendix that, when these conditions hold, mimicking is unprofitable also globally.

Legislator's point of view. Integrating equation (8) we have:

$$u(\theta) = u(\underline{\theta}) + R \int_{\underline{\theta}}^{\theta} Q_{\theta}(s(x), x) dx \quad \forall \theta \geq \underline{\theta}. \quad (9)$$

Notice that the above rent increases with $s(x)$ — i.e., a more corroborating testimony amplifies the agent's mimicking incentives — while it decreases with $\underline{\theta}$ — i.e., a more severe rationing implies fewer mimicking opportunities.

Finally, the following rationing constraint must hold:

$$u_0 \geq \max_{\hat{\theta} \geq \underline{\theta}} u(\hat{\theta}, \theta) \quad \forall \theta < \underline{\theta}, \quad (10)$$

stating that rationed types must wish to face the trial rather than mimicking those who can access the program.

We can now turn to solve the boss' and Legislator's optimization problems. As before, the crime is committed if and only if:

$$\pi \geq \underline{\pi}(\varphi) \equiv \int_0^{\underline{\theta}} (q(\theta) S_p - u_0) dF(\theta) + \int_{\underline{\theta}}^{\bar{\theta}} (Q(s(\theta), \theta) S_p - u(\theta)) dF(\theta).$$

Hence, the Legislator optimization program is:

$$\max_{\varphi} \Pr(\pi \leq \underline{\pi}(\varphi)),$$

subject to (6), (7), (9), (10).

Neglecting the second-order local incentive constraint (6) and the rationing constraint (10), which will be verified ex-post, inserting (9) into the maximand and integrating by parts, we have:

$$\mathcal{P} : \max_{\underline{\theta}, s(\cdot)} \left\{ \int_0^{\underline{\theta}} (q(\theta) S_p - u_0) dF(\theta) + \int_{\underline{\theta}}^{\bar{\theta}} \left[Q(s(\theta), \theta) S_p - u_0 - R Q_{\theta}(s(\theta), \theta) \frac{1 - F(\theta)}{f(\theta)} \right] dF(\theta) \right\}.$$

The key difference between complete and asymmetric information rests upon a simple but fairly general argument. In order to elicit truthful information revelation the Legislator needs to give up an information rent to a whistleblower and this rent generates a positive externality on the boss' ex-ante profit. This is because rents granted by the Legislator ex post, translate onto lower wages that the boss has to pay to the agent ex ante, thus making the crime more profitable (other things being equal). By the same token, limiting the subset of types eligible for the program — i.e., a tighter floor $\underline{\theta}$ — also stifles the boss' crime return. This restriction, however, comes at a cost: excluding potential informants from the program generates a positive externalities on the boss's expected utility as long as the information of these excluded types is very productive — i.e., if the difference $Q(s(\theta), \theta) - q(\theta)$ is not negligible.

Proposition 2 *Assume A1-A4. The second-best policy φ^{sb} has the following properties:*

- (Rationing) *There exists a lower bound $\underline{\theta}^{sb} > 0$ such that all types θ above $\underline{\theta}^{sb}$ are admitted into the program and prefer to blow the whistle in equilibrium, all types below $\underline{\theta}^{sb}$ prefer to opt-out and face the trial. The bound $\underline{\theta}^{sb}$ is determined by the following condition:*

$$(Q(s^{sb}(\underline{\theta}^{sb}), \underline{\theta}^{sb}) - q(\underline{\theta}^{sb}))S_p - RQ_\theta(s^{sb}(\underline{\theta}^{sb}), \underline{\theta}^{sb}) \frac{1 - F(\underline{\theta}^{sb})}{f(\underline{\theta}^{sb})} = 0, \quad (11)$$

- (Partial disclosure) *All agents admitted into the program provide a downward distorted testimony — i.e., $s^{sb}(\theta) \leq \theta$ with equality only at $\theta = \bar{\theta}$ and $s^{sb}(\theta)$ being solution of:*

$$Q_s(s^{sb}(\theta), \theta)S_p - RQ_{s\theta}(s^{sb}(\theta), \theta) \frac{1 - F(\theta)}{f(\theta)} = 0, \quad (12)$$

with $\dot{s}^{sb}(\theta) > 0$.

- (Excessive amnesty) *The second-best amnesty $\phi^{sb}(\theta)$ is larger than the first-best for every θ — i.e.,*

$$\phi^{sb}(\theta) = \underbrace{1 - p + (1 - Q(s^{sb}(\theta), \theta)) \frac{R}{S_a}}_{\text{Zero Rent Amnesty}} + \underbrace{\frac{R}{S_a} \int_{\underline{\theta}^{sb}}^{\theta} Q_\theta(s^{sb}(x), x) dx}_{\text{Bonus } B^{sb}(\theta) \geq 0} > \phi^{fb}(\theta), \quad (13)$$

with $\dot{\phi}^{sb}(\theta) < 0$ and $\dot{B}^{sb}(\theta) > 0$.

The second-best policy trades off the social costs and benefits of a leniency program. The information floor $\underline{\theta}^{sb}$ is determined so as to account for the rent-effect that asymmetric information adds to the entry process into the program. A smaller support of types admitted into the program — i.e., a higher $\underline{\theta}^{sb}$ — stifles the agent's mimicking possibilities, whereby reducing his ex post information rent. This rent-reduction effect due to rationing translates onto the boss' expected utility: lower ex post rents for the agent imply higher expected wages and thus higher costs for the boss. On the other side, however, a smaller support of types also stifles the boss' risk of prosecution whereby reducing his expected profits. On the balance, the second-best policy calls for stricter eligibility criteria relative to the first-best one.

Interestingly, by creating less conflict between the boss and the agent, stricter eligibility criteria increase the wage that the former has to pay to the latter, whereby stifling the equilibrium crime rate. The same type of intuition also explains why the second-best policy does not feature full disclosure: to limit mimicking opportunities, and the implied rents, the Legislator is forced to require downward distorted testimonies.

Finally, note that the amnesty rate satisfies the local incentive compatibility constraint (5) and is set to make the marginal type $\underline{\theta}^{sb}$ indifferent between talking or facing the trial. This leads to a second-best amnesty that, besides the zero utility level characterizing the complete information benchmark, grants a bonus increasing in θ . Overall, however, the second-best amnesty is decreasing in θ because a cooperating

accomplice with worse information faces a higher likelihood of retaliation and needs to get compensated for bearing such extra risk.

4 Extensions

The partial disclosure result obtained in the previous section is based on two extreme (even though somewhat standard) assumptions: (i) full commitment to the policy; (ii) a welfare criterion requiring (ex ante) minimization of crimes. Hence, although Proposition 2 offers the interesting insights that, under asymmetric information, it is impossible to obtain both full disclosure and amnesty rates that covary with the information disclosed by whistleblowers, one may wonder what kind of distortions are expected to emerge when these assumptions are relaxed. To address this issue, we now extend the benchmark model by studying under what conditions the partial disclosure result weakens and when, instead, it survives. For brevity, throughout, we will highlight only the most interesting features of the optimal policy emerging in each of the new scenarios. Some of the proofs are standard and will be omitted.

4.1 Imperfect commitment

To investigate how our results would change when the commitment hypothesis is relaxed, let us suppose that while the Legislator can commit to a reward schedule $\phi(\theta)$ and a rationing rule $\underline{\theta}$, he *cannot* commit to a policy with partial disclosure — i.e., the testimony $s(\theta)$ can be renegotiated by the prosecutor at the trial stage, that is once the agent has reported θ . For simplicity, all the remaining assumptions are as in the benchmark model. Assuming that there is full commitment to $\underline{\theta}$ and $\phi(\theta)$ seems plausible: in practice, informants are allowed to enter the program if and only if their testimony is estimated to be substantially helpful (this rule was, for instance, introduced by the 2001 reform of the Italian accomplice-witness law); the amnesty is instead usually contracted ex ante by prosecutors and accomplices — see, e.g., Borsellino (2011).

The solution of the game is derived by a backward induction argument. For any report $\hat{\theta}$, the ex-post disclosure policy maximizes $Q(s, \hat{\theta})$, which by assumption **A1** implies $s^{fb}(\hat{\theta}) = \hat{\theta}$. Then, moving backward, the accomplice's ex-ante rent is:

$$u(\hat{\theta}, \theta) = -(1 - \phi(\hat{\theta}))S_a - (1 - Q(\hat{\theta}, \theta))R.$$

Focusing on deterministic allocations¹⁷, incentive compatibility requires:¹⁸

$$u_{\hat{\theta}}(\hat{\theta}, \theta) \Big|_{\hat{\theta}=\theta} = 0 \quad \Leftrightarrow \quad \dot{\phi}(\theta)S_a = 0 \quad \forall \theta \geq \underline{\theta}, \quad (14)$$

¹⁷This restriction is *not* without loss of generality. We focus on deterministic allocations simply because, more generally, the optimal policy might force the agent to mix across reports in order to replicate the partial disclosure outcome obtained with full commitment.

¹⁸It is easy to check that the second order condition is satisfied as long as $Q_{s\theta}(\cdot) \geq 0$.

which holds if and only if the reward is unresponsive to θ — i.e., if $\dot{\phi}(\theta) = 0$ for all θ . The Legislator's optimization program is then:

$$\max_{\underline{\theta}, \phi} \left\{ \int_0^{\underline{\theta}} (q(\theta) S_p + pS_a) dF(\theta) + \int_{\underline{\theta}}^{\bar{\theta}} (Q(\theta, \theta) S_p + (1 - \phi) S_a + (1 - Q(\theta, \theta)) R) dF(\theta) \right\},$$

subject to:

$$pS_a \geq (1 - \phi) S_a + (1 - Q(\theta, \theta)) R \quad \forall \theta \geq \underline{\theta}.$$

The optimal amnesty ϕ is then:

$$(1 - \phi) S_a = pS_a - R \min_{\theta \geq \underline{\theta}} (1 - Q(\theta, \theta)) = pS_a - (1 - Q(\underline{\theta}, \underline{\theta})) R.$$

Hence, the Legislator's program simplifies to:

$$\max_{\underline{\theta}} \left\{ \int_0^{\underline{\theta}} q(\theta) S_p dF(\theta) + \int_{\underline{\theta}}^{\bar{\theta}} (Q(\theta, \theta) S_p + (Q(\underline{\theta}, \underline{\theta}) - Q(\theta, \theta)) R) dF(\theta) \right\},$$

whose solution yields the next result:

Proposition 3 *If the Legislator cannot commit to the testimony s , the optimal policy entails:*

- (Full disclosure) $s(\theta) = s^{fb}(\theta) = \theta$,
- (Rationing) $\underline{\theta} > 0$ solves:

$$(Q(\underline{\theta}, \underline{\theta}) - q(\underline{\theta})) S_p - R Q_{\theta}(\underline{\theta}, \underline{\theta}) \frac{1 - F(\underline{\theta})}{f(\underline{\theta})} = 0.$$

- (Flat amnesty) $\phi(\theta) = 1 - p + (1 - Q(\underline{\theta}^{sb}, \underline{\theta}^{sb})) \frac{R}{S_a}$ for all $\theta \geq \underline{\theta}^{sb}$.

Noteworthy, while the lack of commitment on the disclosure rule leads to full disclosure, it implies too large amnesties, which in turn require excessive rationing to strengthen deterrence. In the more general case where there is partial commitment — i.e., in the scenario where s is renegotiated with probability $\lambda \in (0, 1)$ — the optimal (deterministic) policy still entails partial disclosure, but it lies between the one characterized above and that derived in Proposition 2.¹⁹

4.2 Career and political concerns

In this section we derive the optimal policy in a framework where the Legislator's objective function differs from the crime minimization criterion adopted so far and it involves maximization of the boss conviction

¹⁹In this case $1 - \lambda$ captures the degree of trustworthiness of the Legislator or some reduced form of reputational value that can be gained by committing to the mechanism.

probability. This extension is interesting for the following reasons: (i) a Government designing the policy could be motivated by electoral concerns: an aggressive conviction record may increase the chance of being reelected; (ii) prosecutors, which typically influence the design of these policies, could be motivated by career concerns: depending on their monetary incentives and promotion rules, a more aggressive prosecution behavior can improve their wage and career profile.

In this scenario it is immediate to verify that the optimal policy maximizes:

$$\max_{s(\cdot), \phi(\cdot), \underline{\theta}} \left\{ \int_0^{\underline{\theta}} q(\theta) S_p dF(\theta) + \int_{\underline{\theta}}^{\bar{\theta}} Q(s(\theta), \theta) S_p f(\theta) d\theta \right\},$$

subject to (5), (6) and (7). Hence:

Proposition 4 *If the social goal is to maximize the probability of convicting the boss, then:*

- (Full disclosure) $s(\theta) = s^{fb}(\theta) = \theta$ for all θ ,
- (No rationing) $\underline{\theta} = \underline{\theta}^{fb} = 0$,
- (Flat amnesty) $\phi(\theta) = 1 - p + (1 - Q(0, 0)) \frac{R}{S_a}$ for all θ .

Although there is full disclosure and no rationing as in the first best, the optimal policy in this scenario features excessive amnesties, which create a welfare loss due to a worsened deterrence. An interesting implication of this result is that the excessive recourse to the use of insider information in criminal proceedings does not necessarily imply crime minimization, but may partly reflect political and career concerns. This danger has often thrown doubts on the opportunity of setting up these programs.²⁰ Notice also that the main difference between this extension and the outcome obtained in the imperfect commitment extension (which entails full disclosure as well) is that while there the Legislator cares about deterrence and hence its inability to commit to partial disclosure forces him to ration applications, in the case of career concerns the Legislator does not care about deterrence, whereby admitting all types into the program.

4.3 Substitutable sources of information

While θ and s are likely to be complements for low values of available evidence — i.e., when the combined evidence is well below what may be necessary to convict the boss — the opposite might be true when θ is large. Hence, to account for this possibility, in this section we assume that:

A5 *There exists a threshold $\theta^* \in \text{int}\Theta$ such that:*

- $Q_{s\theta}(\theta, \theta) \geq 0 \forall \theta \leq \theta^*$ with equality only at θ^* ,
- $Q_{s\theta}(\theta, \theta) < 0 \forall \theta > \theta^*$.

²⁰If the objective function is a convex combination of the crime rate and the probability of convicting the boss the optimal policy will lie between the one characterized above and that discussed in the paper's baseline model.

Again, to minimize changes, we assume that $Q(\cdot)$ is concave in s and that it is maximized at $s = \theta$, that it is increasing and concave in θ and its third order derivatives guarantee concavity of the Legislator's objective function — i.e., $Q_{ss\theta}(\cdot) \geq 0$. Moreover, we will also posit that the testimony s cannot exceed the accomplice's private information θ . Essentially, we restrict the policy to be such that the amount of information released by the accomplice at the trial cannot exceed the evidence he is aware of — i.e., the testimony must be corroborated by the available evidence and cannot be just cheap talk (this assumption will be discussed more in detail in Remark 2 below).

Incentive feasible allocations are still characterized by (5) and (6) together with (7). The Legislator's unrestricted optimization program is:

$$\max_{\underline{\theta}, s(\cdot), u(\theta)} \left\{ \int_0^{\underline{\theta}} (q(\theta) S_p - u_0) dF(\theta) + \int_{\underline{\theta}}^{\bar{\theta}} [Q(s(\theta), \theta) S_p - u(\theta)] dF(\theta) \right\}.$$

subject to:

$$s(\theta) \leq \theta, \quad (15)$$

$$\dot{s}(\theta) Q_{s\theta}(s(\theta), \theta) R \geq 0, \quad (16)$$

$$u(\theta) = u(\underline{\theta}) + R \int_{\underline{\theta}}^{\theta} Q_{\theta}(s(x), x) dx \quad \forall \theta \geq \underline{\theta}. \quad (17)$$

For any $\underline{\theta} \geq 0$ the optimal second best policy $s^{sb}(\theta)$ solves:

$$\max_{s(\cdot), y(\cdot)} \left\{ \int_{\underline{\theta}}^{\bar{\theta}} \left[Q(s(\theta), \theta) S_p - R Q_{\theta}(s(\theta), \theta) \frac{1 - F(\theta)}{f(\theta)} \right] dF(\theta) \right\}.$$

subject to (15) and:

$$-y(\theta) Q_{s\theta}(s(\theta), \theta) R \leq 0, \quad (18)$$

where $\dot{s}(\theta) \equiv y(\theta)$. As noted in Laffont and Guesnerie (1984), the solution of this program features bunching and is characterized below:

Proposition 5 *Under A5 the second best disclosure rule $s^{sb}(\theta)$ has the following features:*

- (Partial and responsive disclosure for low θ) For $\theta \leq \theta^*$ the disclosure policy solves:

$$Q_s(s^{sb}(\theta), \theta) S_p - R Q_{s\theta}(s^{sb}(\theta), \theta) \frac{1 - F(\theta)}{f(\theta)} = 0 \quad \Rightarrow \quad s^{sb}(\theta) \leq \theta,$$

with $\dot{s}^{sb}(\theta) > 0$ and $s^{sb}(\theta^*) = \theta^*$.

- (Partial and unresponsive disclosure for high θ) For all $\theta \geq \theta^*$ the disclosure policy has a bunch: $s^{sb}(\theta) = \theta^*$.

This result shows that with substitutability the partial disclosure result is exacerbated by the bunching issue.

Remark 2: Notice that the constraint $s(\theta) \leq \theta$ does not need to be explicitly imposed when $Q(\cdot)$ (always) displays complementarities between s and θ : as shown in Proposition 2, in that case it would never bind since the second-best policy features partial disclosure in the whole support of types. Under Assumption **A5**, instead, not imposing this additional restriction would lead to policies that require whistleblowers to disclose more information than they actually know — i.e., $s(\theta) > \theta$. Such upward distorted testimonies would, however, not be supported by the hard evidence gathered by prosecutors and brought at the trial. Hence, it seems plausible to assume that the actual testimony is simply the lowest between θ and $s(\theta)$. As observed by judge Borsellino (see, e.g., Borsellino, 2011), requiring whistleblowers to reveal more than what they actually know is typically unfeasible: defendants’ attorneys use to sue accomplices (and the prosecutors handling them) for false testimony when the information reported in court is not fully coherent with the hard evidence brought at the trial. In short, policies that subsidize “bubbling” seem extremely costly not only because they undermine a trial’s final outcome, but also because this could harm prosecutors’ reputation.

4.4 Retribution contingent on testimony

So far we assumed that the retribution loss is constant. However, the agent might prefer to supply less information because the amount of the boss’s retaliation depends on the amount of information revealed. Here we explore the implications of introducing a retaliation loss that is contingent on the accomplice’s testimony. To study how the optimal policy would change in this scenario, let us denote by $R : [0, \bar{\theta}] \rightarrow \mathfrak{R}_+$ the function mapping a testimony s into the loss inflicted to the accomplice by his former partners and assume $R'(s) \geq 0$ — i.e., the more information the accomplice discloses, the harsher is the effort that his former partners spend in trying to punish his defection (the function $R(\cdot)$ can be interpreted as the expected retaliation loss).

With this structure, it is easy to show that the accomplice’s rent is:

$$u(\theta) = u(\underline{\theta}) + \int_{\underline{\theta}}^{\theta} Q_{\theta}(s(x), x) R(s(x)) dx \quad \forall \theta \geq \underline{\theta},$$

with $u(\theta) \geq u_0 = -pS_a$ for all $\theta \geq \underline{\theta}$. Hence, the Legislator’s (relaxed) problem is:

$$\max_{\underline{\theta}, s(\cdot)} \left\{ \int_0^{\underline{\theta}} q(\theta) S_p dF(\theta) + \int_{\underline{\theta}}^{\bar{\theta}} \left[Q(s(\theta), \theta) S_p - R(s(\theta)) Q_{\theta}(s(\theta), \theta) \frac{1 - F(\theta)}{f(\theta)} \right] dF(\theta) \right\}.$$

For simplicity, we keep assuming that $Q_{s\theta}(\cdot) \geq 0$ for all s and θ .²¹ The first-order condition with respect

²¹The same bunching considerations illustrated in the previous extension would apply here if s and θ were substitutes in some region of parameters.

to s entails:

$$Q_s(s^{sb}(\theta), \theta)S_p - \frac{1 - F(\theta)}{f(\theta)} \left[Q_{s\theta}(s^{sb}(\theta), \theta)R(s^{sb}(\theta)) + \underbrace{Q_\theta(s^{sb}(\theta), \theta)R'(s^{sb}(\theta))}_{(+)\text{ Retaliation enhancing effect}} \right] = 0. \quad (19)$$

Hence, the same type of trade-off discussed in the benchmark model is at work here. On the one hand, a very corroborating testimony (i.e., $s(\theta)$ quite close to θ) enhances the likelihood of conviction for the boss, which (ceteris paribus) reduces his earnings and increases welfare. On the other hand, if $s(\theta)$ is too close to θ , the agent's rent increases, which reduces welfare for two reasons now: first, through the complementarity channel emphasized in the benchmark model; second, a more corroborating testimony is punished more harshly and hence it must be complemented by an even higher rent to ensure truthful information revelation: a novel *retaliation enhancing effect* which worsens deterrence.

Proposition 6 *If $R'(s) \geq 0$ then $s^{sb}(\theta) \leq \theta$ for all θ with equality only at $\bar{\theta}$.*

This result shows that if the retaliation loss is contingent on the accomplice's testimony the partial disclosure result still holds.

4.5 Amnesty contingent on conviction

While actual programs are designed so that amnesty is tied to testimony, we now explore the case where the agent who blows the whistle receives amnesty only if the boss is found guilty thanks to his cooperation. Within our framework, this means that the agent enjoys the discount ϕ with probability $Q(s, \theta)$. His expected utility is therefore:

$$u(\hat{\theta}, \theta) = -Q(s(\hat{\theta}), \theta)(1 - \phi(\hat{\theta}))S_a - (1 - Q(s(\hat{\theta}), \theta))(R + S_a).$$

Local incentive compatibility implies:

$$\dot{u}(\theta) = Q_\theta(s(\theta), \theta)(R + \phi(\theta)S_a) > 0,$$

so that:

$$u(\theta) = u(\underline{\theta}) + \int_{\underline{\theta}}^{\theta} Q_\theta(s(x), x)(R + \phi(x)S_a)dx,$$

with $u(\theta) \geq u_0 = -pS_a$ for all $\theta \geq \underline{\theta}$. The Legislator's optimization program is then:

$$\max_{s(\cdot), \phi(\cdot), \underline{\theta}} \left\{ \int_0^{\underline{\theta}} q(\theta)S_p dF(\theta) + \int_{\underline{\theta}}^{\bar{\theta}} \left[Q(s(\theta), \theta)S_p - (R + \phi(\theta)S_a)Q_\theta(s(\theta), \theta) \frac{1 - F(\theta)}{f(\theta)} \right] dF(\theta) \right\},$$

whose solution is characterized in the next result:

Proposition 7 *If legal benefits are granted to the informant only when the boss is convicted, the optimal policy entails:*

- *A flat amnesty:*

$$\phi = \frac{R}{S_a} \left[\frac{1 - Q(s(\underline{\theta}), \underline{\theta})}{Q(s(\underline{\theta}), \underline{\theta})} \right] \quad \forall \theta \geq \underline{\theta}.$$

- *Partial disclosure — i.e., $s(\theta) \leq \theta$ with equality only at $\bar{\theta}$, where $s(\theta)$ solves:*

$$Q_s(s(\theta), \theta)S_p - (R + \phi S_a)Q_{\theta s}(s(\theta), \theta) \frac{1 - F(\theta)}{f(\theta)} = 0, \quad \forall \theta \geq \underline{\theta}.$$

- *Rationing — i.e., the floor $\underline{\theta} > 0$ solves:*

$$(Q(s(\underline{\theta}), \underline{\theta}) - q(\underline{\theta}))S_p - (R + \phi S_a)Q_{\theta}(s(\underline{\theta}), \underline{\theta}) \frac{1 - F(\underline{\theta})}{f(\underline{\theta})} = 0.$$

The optimal policy still requires partial disclosure. This is because (as in the benchmark model) the agents' rent is increasing in $s(\cdot)$, which has to be distorted for rent extraction purposes. Notice also that: (i) for any given policy requiring a positive amnesty, the above objective function is lower than that obtained in the benchmark model; and (ii) the optimal policy converges to the second-best one when $S_a \rightarrow 0$. Hence, welfare cannot be higher when the policy ties the legal benefit to the trial outcome. This result may explain why, in practice, the amnesty granted to informants is not tied to the trial outcome: under this rule the accomplice would bear too much risk, which should be compensated by an excessively generous amnesty, which would in turn weaken deterrence and harm social welfare.

4.6 The role of protection

A major obstacle to cooperation in criminal proceedings is the risk of retribution by former partners. To avoid this danger, legislations often award protection to flipping criminals. To understand the role of this additional instrument, in this section we enable the Legislator to commit to a protection standard in addition to set the policy already considered in the benchmark model.

Suppose that the Legislator can secure a protection standard η to the cooperating accomplice. This variable belongs to the interval $[0, 1]$ and it measures the probability that the boss' retaliation attempt fails. As before we assume that the retaliation loss R materializes only when the boss is acquitted, whose probability is $1 - Q(\cdot)$, and if the protection program fails, which occurs with probability $1 - \eta$. Protection is costly, and $c(\eta)$ is its increasing and strictly convex cost, which satisfies the Inada conditions $c(0) = c'(0) = 0$ and $c'(1) = +\infty$. Moreover, for the sake of tractability, we assume that the crime return π is distributed uniformly over the compact support $[0, 1]$.

By standard techniques, the agent's rent is:

$$u(\theta) = u(\underline{\theta}) + (1 - \eta) R \int_{\underline{\theta}}^{\theta} Q_{\theta}(s(x), x) dx \quad \forall \theta \geq \underline{\theta}, \quad (20)$$

with $u(\theta) \geq -pS_a$ for all $\theta \geq \underline{\theta}$. The role of protection can be easily understood by inspecting the above rent: it is easy to verify that a larger η reduces $u(\theta)$ and hence relaxes the incentive problem between the legislator and the accomplice. The optimal policy then solves:

$$\max_{\underline{\theta}, s(\cdot)} \left\{ \int_0^{\underline{\theta}} q(\theta) S_p dF(\theta) + \int_{\underline{\theta}}^{\bar{\theta}} \left[Q(s(\theta), \theta) S_p - (1 - \eta) R Q_{\theta}(s(\theta), \theta) \frac{1 - F(\theta)}{f(\theta)} \right] dF(\theta) \right\} - (1 + \lambda) c(\eta).$$

where the parameter $\lambda > 0$ can be interpreted as the shadow cost of public funds, which reflects either inefficiencies of the taxation system or the value of alternative uses of these funds.²² The solution of this program is characterized in the next proposition.

Proposition 8 *With protection, the optimal second-best policy has the following features:*

- (Rationing) The rationing floor $\underline{\theta}^{sb}$ solves:

$$(Q(s^{sb}(\underline{\theta}^{sb}), \underline{\theta}^{sb}) - q(\underline{\theta}^{sb})) S_p - (1 - \eta^{sb}) R Q_{\theta}(s^{sb}(\underline{\theta}^{sb}), \underline{\theta}^{sb}) \frac{1 - F(\underline{\theta}^{sb})}{f(\underline{\theta}^{sb})} = 0,$$

- (Partial disclosure) The disclosure rule is downward distorted: $s^{sb}(\theta) \leq \theta$ with equality only at $\theta = \bar{\theta}$ and $s^{sb}(\theta)$ being the solution of:

$$Q_s(s^{sb}(\theta), \theta) S_p - (1 - \eta^{sb}) R Q_{\theta s}(s^{sb}(\theta), \theta) \frac{1 - F(\theta)}{f(\theta)} = 0,$$

- (Positive protection) There is positive protection $\eta^{sb} > 0$, with η^{sb} being the solution of:

$$c'(\eta^{sb}) = \frac{R}{1 + \lambda} \int_{\underline{\theta}^{sb}}^{\bar{\theta}} \left\{ Q_{\theta}(s^{sb}(\theta), \theta) \frac{1 - F(\theta)}{f(\theta)} \right\} dF(\theta).$$

- (Excessive amnesty) The optimal amnesty still features a type-dependent bonus and is pinned down by the expression of the rent (20).

One interesting aspect to notice here is that the first best policy would entail no protection (the proof of this claim is immediate). Indeed, the need for protection in our model emerges simply because it allows to relax the incentive problem between the accomplice and the Legislator, whereby affecting the positive externality between the information rent and the crime return.

²²See for instance Laffont and Tirole (1993).

5 Self-reporting by the boss

Up to now, we have considered a policy that grants an amnesty only to the agent. What would happen if this benefit is extended to a self-reporting boss as well? Would such a policy be desirable? The historical evidence shows that, occasionally, even leaders of criminal organizations decide to cooperate with the justice by cheating their relatives, former allies and ‘employees’.²³ In this section we modify the baseline model to encompass this possibility. The objective is to show that dealing directly with a self-confessing boss might be necessary to efficiently fight organized crime.

Hence, suppose that the Legislator grants an amnesty Φ to the self-reporting boss as a reward for his cooperation. The structure of the game is similar to that analyzed before:

- **t=0:** the Legislator commits to a policy $\varphi_\Phi = (\mathcal{L}, \underline{\theta}, \Phi)$.
- **t=1:** as in the baseline model.
- **t=2:** A realization of θ materializes. The investigation opens: the boss and the agent simultaneously decide whether to cooperate. If they both blow the whistle, the Legislator decides whom to listen. If the boss self-reports, the agent is convicted with probability P .
- **t=3:** as in the baseline model.

To capture in the simplest possible way the idea that the information provided by a self-confessing boss is more reliable than the agent’s imperfect testimony we assume that the latter is convicted with certainty when the former self-reports — i.e., $P = 1 \geq Q(s, \theta)$ for each θ and s .²⁴ Moreover, we denote by $\delta \geq 0$ the additional cost that the boss bears when cheating his fellow. This parameter reflects both the foregone profits from ceasing criminal activities due to cooperating and the psychological costs incurred by a mobster that gives up a command position and reneges his criminal ‘culture’.

We make the following additional hypothesis:

A6 δ is large enough relative to the boss’ expected sanction in the absence of leniency — i.e.,

$$\delta > q(\bar{\theta})S_p. \tag{21}$$

Equation (21) rules out the uninteresting case where the boss blows the whistle when the agent is not allowed to talk, which would be at odds with the available anecdotal evidence.²⁵

²³For instance, once convicted, Frank Lucas (the leader of one of the most powerful criminal organizations in New York during the 70s) provided evidence that led to more than 100 convictions.

²⁴While we believe that the boss possess better information than the agent, the assumption that this information leads to conviction with certainty is made only for simplicity.

²⁵In Italy, for instance, the earliest whistleblowers were simple soldiers, even Buscetta (the first important ‘pentito’) never reached the status of leader within the organization, it was only a few years after the introduction of the accomplice-witnesses program that the first important bosses started their cooperation — e.g., Giovanni Brusca and Giuseppe Di Cristina in Sicily, Carmine Alfieri and Domenico Bidognetti in Campania and Francesco Fonti in Calabria (Falcone, 1991).

Before characterizing the optimal policy it is worthwhile discussing some key features of an equilibrium outcome of the new game. To make the problem interesting, we will focus on equilibria where, to improve efficiency, the Legislator grants a positive amnesty to the boss and this rate is large enough to guarantee self-reporting in a non-empty set of contingencies. Hence, the equilibrium description must specify not only the states where the boss self-reports, but also the ‘off-equilibrium’ actions that sustain this outcome. To understand why, consider an equilibrium candidate where the boss is expected to self-report in state θ and suppose that unexpectedly he deviates. Is this profitable? The answer depends on what happens in the continuation game following the boss’ unexpected action, which in turn depends on the agent’s behavior at the reporting stage. If the boss’s belief is that the agent is willing to talk in state θ (a conjecture that will hold at the optimal policy), under **A6** the boss’ deviation is unprofitable when:

$$Q(s(\theta), \theta) S_p \geq (1 - \Phi) S_p + \delta, \quad (22)$$

stating that the boss’ expected sanction when he deviates exceeds the utility from self-reporting.²⁶

We look for a cutoff equilibrium where in some states neither the agent nor the boss talk, in some other states only the agent blows the whistle, while in the rest of the cases both of them apply to the program, but only the boss is allowed to self-report (while the agent’s application is rejected). In order to describe this outcome, two relevant thresholds need to be characterized: (i) $\underline{\theta} > 0$ below which no agent is admitted into the program (precisely as before), and (ii) $\underline{\theta}(\Phi)$ above which the boss self-reports.

Given a policy φ_Φ , for any $\theta > \underline{\theta}$ the boss decides to self-report if and only if inequality (22) holds. Consider any incentive compatible policy specifying a disclosure rule $s(\theta)$, such that $s(\theta) \leq \theta$ and $\dot{s}(\theta) \geq 0$. Denote by $\underline{\theta}(\Phi)$ the solution with respect to θ of (22) taken as an equality, then in all states above this cutoff — i.e., $\theta \geq \underline{\theta}(\Phi)$ — the boss gains from self-reporting.

Of course, if δ is large enough, the boss never self-reports and the optimal policy is the same as that characterized in the benchmark model.²⁷ This applies, for instance, to organizations such as the ‘Ndrangheta, where leadership is inherited on a ‘blood relationship’ basis. However, the Mafia and the Camorra feature a different pattern: command positions in these organizations do not necessarily follow the bloodline and are usually the outcome of interior fights. Hence, we assume that:

A7 The cost of self-reporting δ is such that the boss self-reports at least in some states:

$$Q(\bar{\theta}, \bar{\theta}) S_p > \delta. \quad (23)$$

Intuitively, **A7** implies that for Φ sufficiently close to 1 the boss self-reports in states close to $\bar{\theta}$.²⁸

²⁶Also in this case we assume that the boss self-reports whenever indifferent between cooperating and facing the uncertainty of the trial.

²⁷Suppose that there exists some exogenous limit $\bar{\Phi} > 0$ to the amnesty that can be granted to the self-reporting boss. Then, for every finite $\bar{\Phi}$, there exists a finite $\bar{\delta}$ such that for $\delta > \bar{\delta}$ the boss never self-reports — i.e., $\delta > \bar{\delta} \equiv [Q(\bar{\theta}, \bar{\theta}) + (\bar{\Phi} - 1)] S_p$.

²⁸Of course, this is only a sufficient condition and is made only for simplicity. More generally, for any given δ , there exists a Φ sufficiently large such that the equivalent of (23) holds.

Notice also that because $q(\bar{\theta}) < Q(\bar{\theta}, \bar{\theta})$, **A6** and **A7** can be met altogether. Finally, to guarantee uniqueness of the optimal policy we also posit that $Q(\theta, \theta)$ exhibits ‘decreasing marginal returns’ — i.e.,

A8 The function $Q(\theta, \theta)$ is strictly concave in θ and satisfies the Inada condition $Q_\theta(0, 0) = +\infty$.²⁹

We now begin the analysis with the following preliminary result.

Lemma 1 *Assume **A1-A4** and **A6-A8**. For any disclosure rule $s(\theta)$, such that (i) $0 \leq s(\theta) \leq \theta$, (ii) $s(0) = 0$ and $s(\bar{\theta}) = \bar{\theta}$, and (iii) $\dot{s}(\theta) \geq 0$, there exists an upper-bound $\bar{\Phi} < 1$ and a lower-bound $\underline{\Phi}$, with $\underline{\Phi} \in (0, \bar{\Phi})$, such that:*

- for all $\Phi < \underline{\Phi}$ the boss never self-reports — i.e., $\underline{\theta}(\Phi) = \bar{\theta}$;
- for all $\Phi > \bar{\Phi}$ the boss always self-reports — i.e., $\underline{\theta}(\Phi) = 0$;
- for every $\Phi \in (\underline{\Phi}, \bar{\Phi})$ there exists a cutoff $\underline{\theta}(\Phi) > 0$ such that the boss self-reports for $\theta \geq \underline{\theta}(\Phi)$, while he doesn't for $\theta < \underline{\theta}(\Phi)$.

The intuition for this result is straightforward. Under **A7** a too generous amnesty — i.e., Φ larger than $\bar{\Phi}$ — leads the boss to plea guilty and cheat his fellow, while a too restrictive discount — i.e., Φ smaller than $\underline{\Phi}$ — discourages self-reporting. For intermediate values of Φ there is a non-empty subset of Θ where the boss prefers not to self-report, while in the complementary region he is willing to blow the whistle.

First-best policy: Let us briefly illustrate the first-best policy with self-reporting.

Proposition 9 *Assume **A1-A4** and **A6-A8**. The first-best policy φ_Φ^{fb} features the same properties as in Proposition 1 — i.e., no rationing and full disclosure. Moreover, the boss self-reports for all $\theta \geq \underline{\theta}(\Phi^{fb})$, where $\underline{\theta}(\Phi^{fb})$ and $\Phi^{fb} \in (0, 1)$ solve:*

$$Q(\underline{\theta}(\Phi^{fb}), \underline{\theta}(\Phi^{fb}))S_p = (1 - \Phi^{fb})S_p + \delta, \quad (24)$$

$$\underbrace{\frac{(1-p)S_a}{Q_\theta(\underline{\theta}(\Phi^{fb}), \underline{\theta}(\Phi^{fb}))}}_{\text{Domino effect}} = \underbrace{\frac{1 - F(\underline{\theta}(\Phi^{fb}))}{f(\underline{\theta}(\Phi^{fb}))}}_{\text{Crime-enhancing effect}} S_p, \quad (25)$$

where $0 < \underline{\theta}(\Phi^{fb}) < \bar{\theta}$, so that the agent whistles only if $\theta \leq \underline{\theta}(\Phi^{fb})$.

Hence, allowing the boss to self-report is socially beneficial even under complete information. This is for reasons that are completely different from those highlighted in Kaplow and Shavell (1994). In their model self-reporting is unambiguously good for welfare as it saves enforcement resources (individuals who report their harmful acts need not be detected) and reduces risk (self-reporting criminals bear certain rather

²⁹The Inada condition above allows to safely focus on interior solutions, and can be easily relaxed by $Q_\theta(0, 0) = K$ with K finite but large enough.

than uncertain sanctions). In our hierarchical set-up, instead, self-reporting entails benefits but also costs. First, when the boss self-reports, the agent is convicted with certainty: a sort of *domino effect* that spurs the agent's conviction risk and translates onto a higher reservation wage that, in turn, reduces the crime rate.³⁰ Second, the fact that in all states larger than $\underline{\theta}(\Phi^{fb})$ the self-reporting boss enjoys a lighter sanction, weakens deterrence, and therefore reduces welfare by increasing the crime rate: a *crime enhancing* effect.

Second-best policy: Consider now the case of asymmetric information. Clearly, the optimal Φ will also reflect the rent that the agent obtains in equilibrium. It is easy to verify that the agent's participation, rationing and (local) incentive compatibility constraints are as before.

We assume (and verify ex post) that $\bar{\theta} > \underline{\theta}(\Phi) > \underline{\theta}$, recalling that $\underline{\theta}(\Phi)$ solves (22) as equality. The boss' expected sanction is:

$$C(\varphi_\Phi) \equiv \int_0^{\underline{\theta}} q(\theta) S_p dF(\theta) + \int_{\underline{\theta}}^{\underline{\theta}(\Phi)} Q(s(\theta), \theta) S_p dF(\theta) + \int_{\underline{\theta}(\Phi)}^{\bar{\theta}} ((1 - \Phi) S_p + \delta) dF(\theta).$$

By the same token, the agent's break-even wage is:

$$w(\varphi_\Phi) + \int_0^{\underline{\theta}} u_0 dF(\theta) + \int_{\underline{\theta}}^{\underline{\theta}(\Phi)} u(\theta) dF(\theta) + \int_{\underline{\theta}(\Phi)}^{\bar{\theta}} S_a dF(\theta) = 0,$$

Following the same procedure as before, we have:

$$\begin{aligned} \underline{\pi}(\varphi_\Phi) \equiv & \int_0^{\underline{\theta}} (q(\theta) S_p - u_0) dF(\theta) + \int_{\underline{\theta}}^{\underline{\theta}(\Phi)} (Q(s(\theta), \theta) S_p - u(\theta)) dF(\theta) + \\ & + \int_{\underline{\theta}(\Phi)}^{\bar{\theta}} (S_a + (1 - \Phi) S_p + \delta) dF(\theta). \end{aligned}$$

Hence, the Legislator solves the following relaxed program:

$$\begin{aligned} \mathcal{P}_\Phi : \quad \max_{\underline{\theta}, s(\cdot), \Phi} & \left\{ \int_0^{\underline{\theta}} (q(\theta) S_p - u_0) dF(\theta) + \int_{\underline{\theta}(\Phi)}^{\bar{\theta}} (S_a + (1 - \Phi) S_p + \delta) dF(\theta) + \right. \\ & \left. + \int_{\underline{\theta}}^{\underline{\theta}(\Phi)} \left[Q(s(\theta), \theta) S_p - u_0 - RQ_\theta(s(\theta), \theta) \frac{F(\underline{\theta}(\Phi)) - F(\theta)}{f(\theta)} \right] dF(\theta) \right\}. \end{aligned}$$

The next proposition characterizes the solution of this program and defines the second-best policy:

Proposition 10 *Assume A1-A4 and A6-A8. There exists a PBE of the game with self-reporting such that $\bar{\theta} > \underline{\theta}(\Phi^{sb}) > \underline{\theta}_\Phi^{sb} > 0$ and:*

- for $\theta < \underline{\theta}_\Phi^{sb}$ the boss does not self-report and there is no leniency for the agent;

³⁰This domino effect echoes Baccara and Bar-Isaac (2008).

- for $\theta \in [\underline{\theta}_{\Phi}^{sb}, \underline{\theta}(\Phi^{sb})]$ the agent whistles but the boss does not self-report;
- for $\theta > \underline{\theta}(\Phi^{sb})$ both criminals are willing to talk, but only boss-self reports while the agent is sent to trial and convicted with certainty.

This equilibrium behavior is supported by a policy φ_{Φ}^{sb} with the following properties:

- (Rationing) The cutoff $\underline{\theta}_{\Phi}^{sb}$ solves:

$$(Q(s_{\Phi}^{sb}(\underline{\theta}_{\Phi}^{sb}), \underline{\theta}_{\Phi}^{sb}) - q(\underline{\theta}_{\Phi}^{sb}))S_p - RQ_{\theta}(s_{\Phi}^{sb}(\underline{\theta}_{\Phi}^{sb}), \underline{\theta}_{\Phi}^{sb}) \frac{F(\underline{\theta}(\Phi^{sb})) - F(\underline{\theta}_{\Phi}^{sb})}{f(\underline{\theta}_{\Phi}^{sb})} = 0, \quad (26)$$

- (Partial disclosure) For $\theta \in [\underline{\theta}_{\Phi}^{sb}, \underline{\theta}(\Phi^{sb})]$ the optimal testimony $s_{\Phi}^{sb}(\theta)$ solves:

$$Q_s(s_{\Phi}^{sb}(\theta), \theta)S_p - RQ_{s\theta}(s_{\Phi}^{sb}(\theta), \theta) \frac{F(\underline{\theta}(\Phi^{sb})) - F(\theta)}{f(\theta)} = 0, \quad (27)$$

where $s_{\Phi}^{sb}(\theta) \leq \theta$, with equality only at $\theta = \underline{\theta}(\Phi^{sb})$, and $\dot{s}_{\Phi}^{sb}(\theta) > 0$. For $\theta \geq \underline{\theta}(\Phi^{sb})$ there is full disclosure (i.e., $s_{\Phi}^{sb}(\theta) = \theta$) and the amnesty equals to $\phi_{\Phi}^{sb}(\underline{\theta}(\Phi^{sb}))$.

- (Excessive self-reporting) The cutoff $\underline{\theta}(\Phi^{sb})$ and the discount Φ^{sb} solve:

$$Q(\underline{\theta}(\Phi^{sb}), \underline{\theta}(\Phi^{sb}))S_p = (1 - \Phi^{sb})S_p + \delta, \quad (28)$$

$$\underbrace{\frac{(1-p)S_a}{Q_{\theta}(\underline{\theta}(\Phi^{sb}), \underline{\theta}(\Phi^{sb}))}}_{\text{Domino effect}} + \underbrace{\frac{R \int_{\underline{\theta}_{\Phi}^{sb}}^{\underline{\theta}(\Phi^{sb})} Q_{\theta}(s_{\Phi}^{sb}(\theta), \theta) d\theta}{Q_{\theta}(\underline{\theta}(\Phi^{sb}), \underline{\theta}(\Phi^{sb}))}}_{\text{Rent Saving effect}} = \underbrace{\frac{1 - F(\underline{\theta}(\Phi^{sb}))}{f(\underline{\theta}(\Phi^{sb}))} S_p}_{\text{Crime Enhancing effect}}, \quad (29)$$

with $\underline{\theta}_{\Phi}^{sb} < \underline{\theta}(\Phi^{sb}) < \underline{\theta}(\Phi^{fb}) < \bar{\theta}$ and $\Phi^{sb} > \Phi^{fb}$.

- (Excessive amnesty) $\phi_{\Phi}^{sb}(\theta) \geq \phi_{\Phi}^{fb}(\theta)$. Moreover, for $\theta \in [\underline{\theta}_{\Phi}^{sb}, \underline{\theta}(\Phi^{sb})]$, the second-best amnesty with self-reporting is:

$$\phi_{\Phi}^{sb}(\theta) = \underbrace{1 - p + (1 - Q(s_{\Phi}^{sb}(\theta), \theta)) \frac{1}{S_a}}_{\text{Zero Rent Amnesty}} + \underbrace{\frac{R}{S_a} \int_{\underline{\theta}_{\Phi}^{sb}}^{\theta} Q_{\theta}(s_{\Phi}^{sb}(x), x) dx}_{\text{Bonus } B_{\Phi}^{sb}(\theta) \geq 0} \quad (30)$$

with $\dot{\phi}_{\Phi}^{sb}(\theta) < 0$ and $\dot{B}_{\Phi}^{sb}(\theta) > 0$. While $\phi_{\Phi}^{sb}(\theta) = \phi_{\Phi}^{sb}(\underline{\theta}(\Phi^{sb}))$ for $\theta \geq \underline{\theta}(\Phi^{sb})$.

In short, there is one novel force shaping the second best amnesty Φ^{sb} in addition to the *domino* and the *crime enhancing* effects emphasized in Proposition 9. Essentially, granting an amnesty to the self-reporting boss has a beneficial *rent saving effect* that operates through the incentive constraints. A higher amnesty Φ expands the subset of states where the boss self-reports, this diminishes the measure of agents admitted

into the program, which in turn makes mimicking less profitable. This rent-reduction effect reinforces the domino effect, whereby leading the boss to self-report more often than in the complete information case. The second-best policy under self-reporting also differs from the policy characterized in Proposition 2. This is because asymmetric information introduces mimicking opportunities that lead the Legislator to require biased testimonies, and these distortions are positively linked with the measure of agents that blow the whistle in equilibrium. Hence, granting an amnesty to the self-reporting boss allows to mitigate the rent-efficiency trade-off:

Corollary 11 *Assume **A1-A4** and **A6-A8**. Then $s_{\Phi}^{sb}(\theta) > s^{sb}(\theta)$ for all $\theta \in [\underline{\theta}_{\Phi}^{sb}, \underline{\theta}(\Phi^{sb})]$ and $\underline{\theta}_{\Phi}^{sb} < \underline{\theta}^{sb}$. The effect of self-reporting on the optimal agent's amnesty is ambiguous.*

When the boss self-reports there is less need to distort the agent's testimony. This is because (in equilibrium) there will be a lower measure of agents that blow the whistle. Hence, the Legislator needs to waste less rents to elicit truthful information revelation, which allows to request more corroborating testimonies. Precisely the same logic also explains why self-reporting also implies less need for rationing.

The reason why the effect of self-reporting on the agent's amnesty is ambiguous is due to two counter-vailing effects. On the one hand, the amnesty granted to the agent when the boss is allowed to self-report increases because of both better testimonies (higher s) and less rationing (lower $\underline{\theta}$). On the other hand, however, better testimonies also reduce the retaliation risk faced by the agent, which in turn reduces ϕ because it lowers the need for compensating this higher risk.

6 Concluding remarks

The use of insider information in criminal proceeding is widely recognized as one of the main pillars of the 'modern' fight against organized crime. Nevertheless, the implementation of these rules is often undermined by ethical and political concerns. This skepticism calls for a better theoretical understanding of the right responses of the judicial and legal system to the growing organizational complexity and economic/political influence of criminal groups. Keeping this goal in mind, in this paper we have studied the problem of a policy maker designing immunity for privately informed accomplice-witnesses. We focused on a hierarchical criminal organization to capture the basic trade-offs emerging when the efficacy of an accomplice-witnesses program is undermined by an asymmetry of information between the judicial system and criminals willing to testify against their partners in exchange for lighter sanctions. We have identified the main economic forces that may induce informants to release distorted testimonies and, building on the interplay between these effects, we have characterized the second-best policy preventing untruthful information revelation. The main conclusion of the benchmark model is that, contrary to common wisdom, under asymmetric information it is impossible to achieve full information disclosure. This result is mitigated when there is lack of commitment on the Legislator's side and when the policy is designed so as to maximize conviction rates. However, it still holds, and it gets even exacerbated, in a number of extension introducing realistic features of the legal and criminal environments.

7 Appendix

Proof of Proposition 1. Differentiating the objective function of the first-best program with respect to $s(\cdot)$ and $\underline{\theta}$ we have:

$$\begin{aligned}\frac{\partial \pi(\varphi)}{\partial s(\theta)} &= Q_s(s(\theta), \theta), \\ \frac{\partial \pi(\varphi)}{\partial \underline{\theta}} &= (Q(\underline{\theta}^{fb}, \underline{\theta}^{fb}) - q(\underline{\theta}^{fb}))S_p.\end{aligned}$$

Under **A1** these equations immediately imply $s^{fb}(\theta) = \theta$ and $\underline{\theta}^{fb} = 0$. Moreover, the Legislator will induce agents to apply to the program by granting the reservation amnesty $\phi(\cdot)$ that satisfies the participation constraint as equality — i.e.,

$$(1 - \phi^{fb}(\theta))S_a + (1 - Q(\theta, \theta))R = pS_a \quad \forall \theta \in \Theta. \blacksquare$$

Incentive feasible allocations. The characterization of incentive feasible allocations is standard — see, e.g., Laffont and Martimort (2002, Ch., 3). \blacksquare

Proof of Proposition 2. Optimizing pointwisely the objective function in \mathcal{P} with respect to $s(\theta)$ one gets immediately the first-order condition (12), which directly implies $s^{sb}(\theta) \leq \theta$ for all θ with equality only at $\bar{\theta}$ by **A1**. Moreover, optimizing with respect to $\underline{\theta}$ one has the first-order condition (11). Given the pair $(s^{sb}(\theta), \underline{\theta}^{sb})$, the second-best amnesty schedule $\phi^{sb}(\theta)$ has to satisfy two requirements: (i) it has to ensure that the agent's incentive compatibility constraint is met — i.e., it must satisfy (5) evaluated at $s^{sb}(\theta)$; (ii) it must be such that the cutoff type $\underline{\theta}^{sb}$ is indifferent between entering the program and facing the trial — i.e., $u(\underline{\theta}^{sb}) = u_0$. From (9) one has:

$$-(1 - \phi^{sb}(\theta))S_a - (1 - Q(s^{sb}(\theta), \theta))R = u_0 + R \int_{\underline{\theta}^{sb}}^{\theta} Q_{\theta}(s^{sb}(x), x)dx,$$

using $u_0 = -pS_a$:

$$\phi^{sb}(\theta) = 1 - p + (1 - Q(s^{sb}(\theta), \theta))\frac{R}{S_a} + \frac{R}{S_a} \int_{\underline{\theta}^{sb}}^{\theta} Q_{\theta}(s^{sb}(x), x)dx,$$

immediately implying (ii).

Differentiating with respect to θ we have $\dot{\phi}^{sb}(\theta)S_a = -RQ_s(s^{sb}(\theta), \theta)s^{sb}(\theta)$, which implies (i) and $\dot{\phi}^{sb}(\theta) < 0 \Leftrightarrow \dot{s}^{sb}(\theta) > 0$ (which is shown below). Moreover, $\phi^{sb}(\theta) > \phi^{fb}(\theta)$ for all $\theta \geq \underline{\theta}^{sb}$ follows from the fact that $Q(\cdot)$ is concave in s and has a maximum at $s = \theta$:

$$\phi^{sb}(\theta) \geq 1 - p + (1 - Q(\theta, \theta))\frac{R}{S_a} + \frac{R}{S_a} \int_{\underline{\theta}^{sb}}^{\theta} Q_{\theta}(s^{sb}(x), x)dx > 1 - p + (1 - Q(\theta, \theta))\frac{R}{S_a} = \phi^{fb}(\theta).$$

Finally, note that $B^{sb}(\theta) \geq 0$ and $\dot{B}^{sb}(\theta) = Q_{\theta}(s^{sb}(x), x) > 0$.

We now prove that the first-order necessary conditions (11) and (12) are also sufficient for an optimum by showing that the objective of the Legislator's relaxed program \mathcal{P} is strictly concave under **A1-A4**. To

begin with, observe that for any given $\underline{\theta}$ the objective of \mathcal{P} (hereafter $W(\cdot)$ with a little abuse of notation) is strictly concave in $s(\cdot)$ — i.e.,

$$\frac{\partial^2 W(\cdot)}{\partial s(\cdot)^2} = Q_{ss}(s^{sb}(\theta), \theta)S_p - RQ_{ss\theta}(s^{sb}(\theta), \theta)\frac{1-F(\theta)}{f(\theta)} < 0.$$

Differentiating $W(\cdot)$ twice with respect to $\underline{\theta}$ and evaluating at $s^{sb}(\theta)$ one has:

$$\begin{aligned} \frac{\partial^2 W(\cdot)}{\partial \underline{\theta}^2} = & \left\{ -Q_\theta(\cdot) - \dot{s}^{sb}(\cdot) \left(Q_s(\cdot)S_p - RQ_{s\theta}(\cdot)\frac{1-F(\theta)}{f(\theta)} \right) + \right. \\ & \left. + \left(Q_{\theta\theta}(\cdot)\frac{1-F(\theta)}{f(\theta)} + Q_\theta(\cdot)\frac{\partial}{\partial\theta} \left(\frac{1-F(\theta)}{f(\theta)} \right) \right) \frac{R}{S_p} \right\}_{\theta=\underline{\theta}^{sb}}, \end{aligned}$$

which by (12) implies:

$$\frac{\partial^2 W(\cdot)}{\partial \underline{\theta}^2} = \left\{ -Q_\theta(\cdot) + \left(Q_{\theta\theta}(\cdot)\frac{1-F(\theta)}{f(\theta)} + Q_\theta(\cdot)\frac{\partial}{\partial\theta} \left(\frac{1-F(\theta)}{f(\theta)} \right) \right) \frac{R}{S_p} \right\}_{\theta=\underline{\theta}^{sb}}.$$

Assumption **A3** then implies that $\frac{\partial^2 W(\cdot)}{\partial \underline{\theta}^2} < 0$ since $Q_\theta(\cdot) > 0$ and $Q_{\theta\theta}(\cdot) \leq 0$. Moreover, in order to show that $\underline{\theta}^{sb}$ is in the interior of Θ , observe that, under **A1-A2**, the left-hand side of (11) is positive, increasing and nil at $\theta = 0$. In order to establish the optimality of setting a floor $\underline{\theta}^{sb} \in (0, \bar{\theta})$ it is then enough to verify that the right-hand side of (11), i.e.,

$$\Omega(\underline{\theta}^{sb}) \equiv RQ_\theta(s^{sb}(\underline{\theta}^{sb}), \underline{\theta}^{sb})\frac{1-F(\underline{\theta}^{sb})}{f(\underline{\theta}^{sb})S_p},$$

satisfies the following conditions: (i) $\Omega(0) > 0$, (ii) $\Omega(\bar{\theta}) < Q(\bar{\theta}, \bar{\theta}) - q(\bar{\theta})$, and (iii) the function $\Omega(\theta)$ is continuous. Showing that $\Omega(0) > 0$ is immediate. Moreover, showing that $\Omega(\bar{\theta}) < Q(\bar{\theta}, \bar{\theta}) - q(\bar{\theta})$ is also quite simple since $(1-F(\bar{\theta}))/f(\bar{\theta}) = 0$ implies $s^{sb}(\bar{\theta}) = \bar{\theta}$ from (12). Continuity of $\Omega(\theta)$ follows from the hypothesis that the functions $Q(\cdot)$, $q(\cdot)$ and $F(\cdot)$ are twice continuously differentiable.

Finally, to conclude the proof we verify that the policy characterized by (11), (12) and (13) satisfies the second-order local incentive compatibility constraint (6), the global incentive compatibility constraint and the rationing constraint (10).

We first show that (6) is met under **A1-A4**. Since $Q_{s\theta}(\cdot) > 0$ by **A2**, we only need to show that $\dot{s}^{sb}(\theta) \geq 0$. This is straightforward, using (12) the Implicit Function Theorem implies:

$$\dot{s}^{sb}(\theta) = \frac{Q_{s\theta}(\cdot) \left(S_p - R\frac{\partial}{\partial\theta} \left(\frac{1-F(\theta)}{f(\theta)} \right) \right) - RQ_{s\theta\theta}(\cdot)\frac{1-F(\theta)}{f(\theta)}}{-Q_{ss}(\cdot)S_p + RQ_{ss\theta}(\cdot)\frac{1-F(\theta)}{f(\theta)}},$$

where **A2**, **A3** and **A4** imply $\dot{s}^{sb}(\theta) > 0$.

Second, in order to show that the global incentive compatibility constraint holds we need to verify that

there is no $\theta \geq \underline{\theta}^{sb}$ where the agent can profit by announcing $\theta' \geq \underline{\theta}^{sb}$ with $\theta \neq \theta'$ — i.e.,

$$u(\theta, \theta) - u(\theta', \theta) \geq 0 \quad \forall (\theta, \theta') \in [\underline{\theta}^{sb}, \bar{\theta}]^2,$$

which by definition of $u(\theta', \theta)$ implies:

$$(1 - \phi^{sb}(\theta'))S_a + (1 - Q(s^{sb}(\theta'), \theta))R \geq (1 - \phi^{sb}(\theta))S_a + (1 - Q(s^{sb}(\theta), \theta))R. \quad (\text{A1})$$

Assume $\theta' > \theta$, with no loss of generality, then (A1) yields:

$$- \int_{\theta}^{\theta'} \left\{ \dot{\phi}^{sb}(x)S_a + \dot{s}^{sb}(x) Q_s(s^{sb}(x), \theta)R \right\} dx \geq 0,$$

using (5) and substituting for $\dot{\phi}^{sb}(x)S_a = -\dot{s}^{sb}(x) Q_s(s^{sb}(x), x)R$ for $x \geq \theta$:

$$\begin{aligned} 0 &\leq - \int_{\theta}^{\theta'} \left\{ \dot{s}^{sb}(x) Q_s(s^{sb}(x), \theta)R - \dot{s}^{sb}(x) Q_s(s^{sb}(x), x)R \right\} dx = \\ &= - \int_{\theta}^{\theta'} \left\{ \dot{s}^{sb}(x)R \int_x^{\theta} Q_{s\theta}(s^{sb}(x), y)dy \right\} dx. \end{aligned} \quad (\text{A2})$$

which immediately implies the result since $\dot{s}^{sb}(x) \geq 0$, $x \geq \theta$ and $Q_{s\theta}(\cdot) \geq 0$.

Showing that no type $\theta \geq \underline{\theta}^{sb}$ can profit by mimicking a type $\theta' < \underline{\theta}^{sb}$ is obvious given the fact that $\dot{u}(\theta) > 0$. Finally, we show that the rationing constraint is satisfied — i.e., there is no $\theta < \underline{\theta}^{sb}$ such that the agent can profit by announcing $\theta' \geq \underline{\theta}^{sb}$. Formally:

$$u_0 = -pS_a \geq u(\theta', \theta) \quad \forall \theta < \underline{\theta}^{sb} \quad \text{and} \quad \forall \theta' \geq \underline{\theta}^{sb}. \quad (\text{A3})$$

First, observe that by definition of the marginal type $\underline{\theta}^{sb}$ equation (A3) can be rewritten as:

$$u(\underline{\theta}^{sb}) \geq u(\theta', \theta), \quad (\text{A4})$$

moreover, since $Q_{\theta}(\cdot) > 0$ and $\underline{\theta}^{sb} > \theta$ it must be $u(\theta', \underline{\theta}^{sb}) > u(\theta', \theta)$. Inequality (A4) must then hold as long as the following is true:

$$u(\underline{\theta}^{sb}) \geq u(\theta', \underline{\theta}^{sb}) \quad \forall \theta' > \underline{\theta}^{sb},$$

which is true precisely by the same argument used to show that the global incentive compatibility constraint holds for all types $(\theta, \theta') \in [\underline{\theta}^{sb}, \theta]^2$. This concludes the proof. ■

Proof of Proposition 5. We first show that under Assumption **A5** there cannot be full separation of types — i.e., the optimal policy involves bunching. Let $\tilde{s}(\theta)$ be the solution of the standard (full separation) relaxed program:

$$\max_{s(\cdot) \leq \theta} \left\{ \int_{\underline{\theta}}^{\bar{\theta}} \left[Q(s(\theta), \theta) S_p - RQ_{\theta}(s(\theta), \theta) \frac{1 - F(\theta)}{f(\theta)} \right] dF(\theta) \right\}, \quad (\text{A5})$$

and denote by $\tau(\theta)$ the multiplier associated to $s(\theta) \leq \theta$. Optimizing pointwisely with respect to $s(\theta)$ we

have:

$$Q_s(s(\theta), \theta) S_p - RQ_{s\theta}(s(\theta), \theta) \frac{1 - F(\theta)}{f(\theta)} - \tau(\theta) = 0,$$

with the complementary slackness condition $\tau(\theta) > 0$ whenever $s(\theta) = \theta$. Notice that, by **A5**:

$$0 = Q_{s\theta}(\theta^*, \theta^*) > Q_{s\theta}(s, \theta) \quad \forall s < \theta^*.$$

Hence, $\tau(\theta^*) > 0$ at θ^* and $\tilde{s}(\theta) = \theta$ for all $\theta \geq \theta^*$ with:

$$\tau(\theta) = -RQ_{s\theta}(\theta, \theta) \frac{1 - F(\theta)}{f(\theta)} \geq 0 \quad \forall \theta \geq \theta^*.$$

Consider now $\theta < \theta^*$. Denote by $s_0(\theta)$ the solution of the first-order condition with no corners — i.e.,

$$Q_s(s(\theta), \theta) S_p - RQ_{s\theta}(s(\theta), \theta) \frac{1 - F(\theta)}{f(\theta)} = 0.$$

Under **A5**, $Q_{s\theta}(\theta, \theta) > 0$ for $\theta < \theta^*$. Moreover, since $Q_{s\theta}(0, \theta) > 0$ and $Q_{ss\theta}(\cdot) \geq 0$, it follows that $Q_{s\theta}(s, \theta) > 0$ for any $s < \theta$ and $\theta < \theta^*$. Hence, $\tilde{s}(\theta) = s_0(\theta) < \theta$. Clearly, when $\theta < \theta^*$ the second-order local incentive constraint (16) is met, since $s_0(\theta)$ is increasing and $Q_{s\theta}(\cdot) > 0$ in this region of parameters. However, this is not the case for $\theta > \theta^*$, where $\tilde{s}(\theta) = \theta$ and $Q_{s\theta}(\theta, \theta) < 0$. Hence, the solution of the relaxed program does not solve the unrestricted program and it must feature bunching on some interval $\Theta^b = [\theta_1, \theta_2] \subset \Theta$.

Next, we turn to the characterization of the optimal policy. Denote by $\mu(\theta)$ the multiplier of (18) and by $\tau(\theta)$ that of (15). The solution of \mathcal{P} maximizes the following Lagrangian:

$$\mathcal{L}(\cdot) = H(s(\cdot), y(\cdot), \mu(\cdot), \theta) - \tau(\cdot)(s(\cdot) - \theta),$$

where $H(\cdot)$ denotes the following Hamiltonian:

$$H(\cdot) = \left[Q(\cdot) S_p - RQ_{s\theta}(\cdot) \frac{1 - F(\theta)}{f(\theta)} \right] f(\theta) - y(\theta) Q_{s\theta}(\cdot).$$

Using the results obtained in Guesnerie and Laffont (1984), the first-order conditions of this program entail:

$$\dot{\mu}(\theta) = -\frac{\partial \mathcal{L}(\cdot)}{\partial s} = - \left[Q_s(s(\theta), \theta) S_p - RQ_{s\theta}(s(\theta), \theta) \frac{1 - F(\theta)}{f(\theta)} \right] f(\theta) + \mu(\theta) y(\theta) Q_{ss\theta}(s(\theta), \theta) R + \tau(\theta), \quad (\text{A6})$$

with the additional slackness conditions:

$$\mu(\theta) > 0 \text{ if } y(\theta) Q_{s\theta}(s(\theta), \theta) R = 0,$$

$$\tau(\theta) > 0 \text{ if } s(\theta) = \theta.$$

We have already shown that the optimal policy must entail bunching on some interval $\Theta^b = [\theta_1, \theta_2] \subset \Theta$.

Clearly, $\mu(\theta) > 0$ for each $\theta \in \text{int}\Theta^b$ with the two transversality condition being satisfied: $\mu(\theta_1) = \mu(\theta_2) = 0$. Hence, for all $\theta \in \Theta^b$, the optimal disclosure rule is flat and entails $s^{sb}(\theta) = \theta_1$ — i.e., any other policy such that $s^{sb}(\theta) > \theta_1$ for $\theta \in \Theta^b$ would violate the constraint $s(\theta) \leq \theta$.

Integrating over Θ^b we then get:

$$\int_{\theta_1}^{\theta_2} Q_s(\theta_1, x) S_p f(x) dx = R \int_{\theta_1}^{\theta_2} \frac{1 - F(x)}{f(x)} Q_{s\theta}(\theta_1, x) f(x) dx. \quad (\text{A7})$$

The characterization of this subset is articulated in the following steps.

Step 1. For any $\theta_1 < \bar{\theta}$, the solution of \mathcal{P} entails $\theta_2 = \bar{\theta}$ — i.e., $\Theta^b = [\theta_1, \bar{\theta}]$.

The proof is by contradiction. Suppose that $\dot{s}(\theta) = 0$ on $\Theta^b = [\theta_1, \theta_2] \subset \Theta$, with $\bar{\theta} > \theta_2 > \theta_1$. Then, by the first-order condition (A6), $\mu(\theta) = 0$ around $\bar{\theta}$ and $s^{sb}(\bar{\theta}) = \bar{\theta}$. Moreover, by continuity there must exist a neighborhood of $\bar{\theta}$, say $\mathcal{B}(\bar{\theta})$, such that $s^{sb}(\theta) = \min\{s_0(\theta), \theta\}$ for each $\theta \in \Theta \cap \mathcal{B}(\bar{\theta})$ and $\theta > \theta^*$, where $s_0(\theta)$ solves:

$$Q_s(s(\theta), \theta) S_p - R Q_{s\theta}(s(\theta), \theta) \frac{1 - F(\theta)}{f(\theta)} = 0.$$

Hence, $\dot{s}^{sb}(\theta) > 0$ for each $\theta \in \Theta \cap \mathcal{B}(\bar{\theta})$ and $\theta > \theta^*$. But **A5** implies:

$$0 > Q_{s\theta}(\theta, \theta) \geq Q(s, \theta) \quad \forall s \leq \theta, \theta > \theta^*.$$

Then, (18) cannot be met everywhere in Θ if $\bar{\theta} \notin \Theta^b$: a contradiction.

Step 2. $\theta_1 \geq \theta^*$.

Suppose that $\theta_1 < \theta^*$. Differentiating (A6) on Θ^b , it is easy to show that

$$\lim_{\theta \rightarrow \theta_1^+} \ddot{\mu}(\theta) = -R \lim_{\theta \rightarrow \theta_1^+} \left\{ Q_{s\theta}(\theta, \theta) \left[1 - \frac{\partial}{\partial \theta} \left(\frac{1 - F(\theta)}{f(\theta)} \right) \right] \right\},$$

which entails $\lim_{\theta \rightarrow \theta_1^+} \ddot{\mu}(\theta) < 0$ since $Q_{s\theta}(\theta, \theta) > 0$ for $\theta < \theta^*$ by **A5**, and $(1 - F(\theta))/f(\theta)$ is decreasing by **A3**. This fact, together with the transversality condition $\mu(\theta_1) = 0$ and the fact that $\lim_{\theta \rightarrow \theta_1^+} \dot{\mu}(\theta) = 0$ implies that $\mu(\theta) < 0$ for some $\theta > \theta_1$ and close to θ_1 : a contradiction.

Step 3. $\theta_1 \leq \theta^*$.

Suppose that $\theta_1 > \theta^*$. Then, concavity of $Q(\cdot)$ with respect to s entails $Q_s(\theta_1, \theta) > 0$ for all $\theta > \theta_1$ and hence:

$$\int_{\theta_1}^{\bar{\theta}} Q_s(\theta_1, x) S_p f(x) dx > 0. \quad (\text{A8})$$

Moreover, **A5** also implies:

$$0 > Q_{s\theta}(\theta, \theta) > Q_{s\theta}(\theta_1, \theta) \quad \forall \theta_1 \leq \theta, \theta > \theta^*.$$

As a consequence:

$$\int_{\theta_1}^{\bar{\theta}} Q_s(\theta_1, x) S_p f(x) dx < 0. \quad (\text{A9})$$

Inequalities (A8) and (A9) clearly contradict (A7) evaluated at $\theta_2 = \bar{\theta}$: a contradiction.

Gathering Steps 2 and 3, it follows that $\theta_1 = \theta^*$. Hence, $\Theta^b = [\theta^*, \bar{\theta}]$, which concludes the proof. ■

Proof of Proposition 6. The result immediately follows from the fact that the right hand side of (19) is positive and $Q_s(\cdot)$ is concave in s with a maximum at $s = \theta$. Of course, to make the problem concave a few technical requirements must be added — i.e., $R''(s) \geq 0$, $R'(0) = 0$ and $R(0)$ small enough. ■

Proof of Lemma 1. Take any continuously differentiable disclosure rule $s(\theta)$ such that: $s(\theta) \leq \theta$, $s(\bar{\theta}) = \bar{\theta}$, $s(0) = 0$ and $\dot{s}(\theta) \geq 0$. Then, let $\underline{\theta}(\Phi)$ be the solution with respect to θ of:

$$Q(s(\theta), \theta) S_p = (1 - \Phi) S_p + \delta. \quad (\text{A10})$$

By assumption $\underline{\theta}(\Phi)$ exists for some $\Phi > 0$ because $Q(s(\theta), \theta)$ is increasing in θ . Moreover, notice that $\underline{\theta}(\Phi)$ is decreasing in Φ — i.e.,

$$\frac{\partial \underline{\theta}(\Phi)}{\partial \Phi} = - \frac{1}{Q_s(s(\theta), \theta) \dot{s}(\theta) + Q_\theta(s(\theta), \theta)} < 0.$$

We can now show that there exists a $\Phi \in (0, 1)$ such that $\underline{\theta}(\Phi) \in (0, \bar{\theta})$. This is because $\underline{\theta}(\Phi) < \bar{\theta}$ at $\Phi = 1$ by **A7**. Moreover, **A6** implies that at $\Phi = 1$ equation (A10) cannot hold for θ close to 0 and therefore the boss does not self-report in these states. Hence, $\underline{\theta}(\Phi) > 0$. By continuity, this also implies that there must exist a non-empty open set $(\underline{\Phi}, \bar{\Phi})$ such that $\underline{\theta}(\Phi) \in (0, \bar{\theta})$ for all $\underline{\Phi} < \Phi < \bar{\Phi}$. ■

Proof of Proposition 9. To characterize the efficient allocation we will first conjecture a few properties of the equilibrium outcome and the optimal policy, which will be used to characterize the solution of the Legislator's (relaxed) program. Then, we will show that the solution of this program actually satisfies those conjectures and hence yields a global optimum.

Suppose that the optimal policy is such that $\dot{s}_\Phi^{fb}(\theta) \geq 0$ and $\underline{\theta}_\Phi^{fb} < \underline{\theta}(\Phi^{fb}) < \bar{\theta}$. Moreover, assume that for $\theta \geq \underline{\theta}(\Phi^{fb})$ only the boss is allowed to self-report (which according to Lemma 1 is incentive compatible for him) while the agent is sent to trial even if in these states he would be willing to talk. If these properties are satisfied altogether, the Legislator's relaxed optimization problem is:

$$\max_{\underline{\theta}, s(\cdot), \Phi} \Gamma(\cdot) \equiv \max_{\underline{\theta}, s(\cdot), \Phi} \left\{ \int_0^{\underline{\theta}} (q(\theta) S_p + p S_a) dF(\theta) + \int_{\underline{\theta}}^{\underline{\theta}(\Phi)} (Q(s(\theta), \theta) S_p + p S_a) dF(\theta) + \int_{\underline{\theta}(\Phi)}^{\bar{\theta}} (S_a + (1 - \Phi) S_p + \delta) dF(\theta) \right\}.$$

Differentiating with respect to $s(\cdot)$ and $\underline{\theta}$ it is immediate to show that, in an interior solution, the first-best policy with self-reporting features full disclosure and no rationing — i.e., $s_\Phi^{fb}(\theta) = \theta$ for all θ (which also confirms the conjecture that $\dot{s}_\Phi^{fb}(\theta) > 0$) and $\underline{\theta}_\Phi^{fb} = 0$. Next, differentiating with respect to Φ one obtains the first-order condition:

$$-(S_a + (1 - \Phi^{fb}) S_p + \delta) \frac{\partial \underline{\theta}(\Phi^{fb})}{\partial \Phi} - \frac{\int_{\underline{\theta}(\Phi^{fb})}^{\bar{\theta}} S_p dF(\theta)}{f(\underline{\theta}(\Phi^{fb}))} + \frac{\partial \underline{\theta}(\Phi^{fb})}{\partial \Phi} (Q(\underline{\theta}(\Phi^{fb}), \underline{\theta}(\Phi^{fb})) S_p + p S_a) = 0.$$

Note that if $\underline{\theta}(\Phi^{fb}) \in \text{int}\Theta$ then (24) holds at Φ^{fb} . Hence, from **A1** and the implicit Function Theorem, we have:

$$\frac{\partial \underline{\theta}(\Phi^{fb})}{\partial \Phi} = -\frac{1}{Q_{\theta}(\underline{\theta}(\Phi^{fb}), \underline{\theta}(\Phi^{fb}))} < 0.$$

The first-order condition above then boils down to (25).

Now, in order to show that $\underline{\theta}(\Phi^{fb}) < \bar{\theta}$ note that if $\underline{\theta}(\Phi^{fb}) = \bar{\theta}$ equation (25) implies

$$\frac{(1-p)S_a}{Q_{\theta}(\bar{\theta}, \bar{\theta})} > 0, \tag{A11}$$

hence $\underline{\theta}(\Phi^{fb}) < \bar{\theta}$. Moreover, to show that $\underline{\theta}(\Phi^{fb}) > 0$ note that for $\underline{\theta}(\Phi^{fb}) = 0$ equation (25) together with **A7** implies immediately:

$$\frac{(1-p)S_a}{Q_{\theta}(0, 0)} - \frac{S_p}{f(0)} < 0. \tag{A12}$$

Uniqueness of the optimal policy follows from the fact that under **A7** the left hand side of (25) is decreasing in Φ and $\frac{\partial \underline{\theta}(\Phi^{fb})}{\partial \Phi} < 0$, while **A3** together with $\frac{\partial \underline{\theta}(\Phi^{fb})}{\partial \Phi} < 0$ imply that the right hand side of (25) is increasing in Φ .

To conclude the proof we now show that: (i) it is never optimal for the Legislator to reject the boss' self confession when $\theta \geq \underline{\theta}(\Phi^{fb})$; (ii) in these states it is never optimal for the Legislator to allow both criminals to blow the whistle; (iii) $\underline{\theta}(\Phi^{fb}) > \underline{\theta}^{fb}$.

Point (i) is straightforward. Suppose that it is efficient for the Legislator not to allow for self-reporting. This would clearly imply $\underline{\theta}(\Phi^{fb}) = \bar{\theta}$, which however contradicts (A11).

To show (ii) note that if the Legislator commits to grant amnesties to both criminals when they flip altogether — i.e., for $\theta \geq \underline{\theta}(\Phi^{fb})$ — his maximization program is:

$$\begin{aligned} \max_{\underline{\theta}, s(\cdot), \Phi} \Gamma^*(\cdot) \equiv & \max_{\underline{\theta}, s(\cdot), \Phi, \phi} \left\{ \int_0^{\underline{\theta}} (q(\theta) S_p + pS_a) dF(\theta) + \int_{\underline{\theta}}^{\underline{\theta}(\Phi)} (Q(s(\theta), \theta) S_p + pS_a) dF(\theta) + \right. \\ & \left. + \int_{\underline{\theta}(\Phi)}^{\bar{\theta}} ((1-\phi(\theta)) S_a + (1-\Phi)S_p + \delta) dF(\theta) \right\}. \end{aligned}$$

It is then easy to verify that $\Gamma^*(\cdot) \leq \Gamma(\cdot)$ for any given $\phi \geq 0$ and Φ with equality only if Φ is such that $\underline{\theta}(\Phi) = \bar{\theta}$. Hence, the Legislator strictly prefers to listen only to the self-reporting boss whenever both criminals are willing to cooperate.

Finally, showing that $\underline{\theta}(\Phi^{fb}) > \underline{\theta}^{fb}$ is immediate since $\underline{\theta}_{\Phi}^{fb} = 0$ and $\underline{\theta}(\Phi^{fb}) > 0$ by (A12). ■

Proof of Proposition 10: As in the proof of Proposition 9, to characterize the optimal allocation under asymmetric information we will first conjecture a few properties of the equilibrium outcome and the optimal policy, which will be used to characterize the solution of the Legislator's (relaxed) program. Then, we will show that the solution of this program actually satisfies those conjectures and hence yields a global optimum.

Suppose that the optimal policy is such that $\dot{s}_{\Phi}^{sb}(\theta) \geq 0$ and $\underline{\theta}_{\Phi}^{sb} < \underline{\theta}(\Phi^{sb}) < \bar{\theta}$. Moreover, assume that for $\theta \geq \underline{\theta}(\Phi^{sb})$ only the boss is allowed to self-report (which according to Lemma 1 is incentive compatible for him) while the agent is sent to trial even if in these states he would be willing to talk. When these properties are satisfied, it is easy to show that the Legislator's relaxed problem is \mathcal{P}_{Φ} .

Differentiating with respect to $\underline{\theta}$ and $s(\cdot)$ yields the first-order conditions (26) and (27). Then, by the same techniques used in the proof of Proposition 2, it follows that: $\underline{\theta}_{\Phi}^{sb} \in \text{int}\Theta$, $s_{\Phi}^{sb}(\theta) \leq \theta$ with equality only at $\theta = \underline{\theta}(\Phi^{sb})$ and $\dot{s}_{\Phi}^{sb}(\theta) \geq 0$, and that (30) yields the agent's optimal amnesty.

Next, we show that (29) identifies the optimal amnesty for the self-reporting boss, and that $\underline{\theta}_{\Phi}^{sb} < \underline{\theta}(\Phi^{sb}) < \bar{\theta}$. First, differentiating the objective of \mathcal{P}_{Φ} with respect to Φ and using the fact that by (27) $s_{\Phi}^{sb}(\underline{\theta}(\Phi^{sb})) = \underline{\theta}(\Phi^{sb})$ one gets:

$$-(S_a + (1 - \Phi^{sb})S_p) + \delta \frac{\partial \underline{\theta}(\Phi^{sb})}{\partial \Phi} - \frac{\int_{\underline{\theta}(\Phi^{sb})}^{\bar{\theta}} S_p dF(\theta)}{f(\underline{\theta}(\Phi^{sb}))} + \\ + (Q(\underline{\theta}(\Phi^{sb}), \underline{\theta}(\Phi^{sb})))S_p + pS_a) \frac{\partial \underline{\theta}(\Phi^{sb})}{\partial \Phi} - \frac{\partial \underline{\theta}(\Phi^{sb})}{\partial \Phi} R \int_{\underline{\theta}_{\Phi}^{sb}}^{\underline{\theta}(\Phi^{sb})} Q_{\theta}(s_{\Phi}^{sb}(\theta), \theta) d\theta = 0.$$

Since $\underline{\theta}(\Phi^{sb}) \in \text{int}\Theta$, condition (28) holds by definition — i.e.,

$$Q(\underline{\theta}(\Phi^{sb}), \underline{\theta}(\Phi^{sb}))S_p = (1 - \Phi^{sb})S_p + \delta,$$

hence, the first-order condition with respect to Φ calculated above becomes:

$$(1 - p)S_a \frac{\partial \underline{\theta}(\Phi^{sb})}{\partial \Phi} + \frac{\int_{\underline{\theta}(\Phi^{sb})}^{\bar{\theta}} S_p dF(\theta)}{f(\underline{\theta}(\Phi^{sb}))} + \frac{\partial \underline{\theta}(\Phi^{sb})}{\partial \Phi} R \int_{\underline{\theta}_{\Phi}^{sb}}^{\underline{\theta}(\Phi^{sb})} Q_{\theta}(s_{\Phi}^{sb}(\theta), \theta) d\theta = 0. \quad (\text{A13})$$

Differentiating (28) and using the fact that $s_{\Phi}^{sb}(\underline{\theta}(\Phi^{sb})) = \underline{\theta}(\Phi^{sb})$ by (27), which implies $Q_s(\underline{\theta}(\Phi^{sb}), \underline{\theta}(\Phi^{sb})) = 0$ by **A1**, we have:

$$\frac{\partial \underline{\theta}(\Phi^{sb})}{\partial \Phi} = -\frac{1}{Q_{\theta}(\underline{\theta}(\Phi^{sb}), \underline{\theta}(\Phi^{sb}))} < 0. \quad (\text{A14})$$

Hence, (A13) rewrites as:

$$\frac{(1 - p)S_a + R \int_{\underline{\theta}_{\Phi}^{sb}}^{\underline{\theta}(\Phi^{sb})} Q_{\theta}(s_{\Phi}^{sb}(\theta), \theta) d\theta}{Q_{\theta}(\underline{\theta}(\Phi^{sb}), \underline{\theta}(\Phi^{sb}))} = \frac{1 - F(\underline{\theta}(\Phi^{sb}))}{f(\underline{\theta}(\Phi^{sb}))} S_p, \quad (\text{A15})$$

which yields (29).

Now, to show that $\underline{\theta}(\Phi^{sb}) < \bar{\theta}$ note that for $\underline{\theta}(\Phi^{sb}) = \bar{\theta}$ the first-order condition (A15) yields:

$$\frac{(1 - p)S_a + R \int_{\underline{\theta}_{\Phi}^{sb}}^{\bar{\theta}} Q_{\theta}(s_{\Phi}^{sb}(\theta), \theta) d\theta}{Q_{\theta}(\bar{\theta}, \bar{\theta})} > 0, \quad (\text{A16})$$

hence $\underline{\theta}(\Phi^{sb}) < \bar{\theta}$. We then need to show that $\underline{\theta}(\Phi^{sb}) > \underline{\theta}_{\Phi}^{sb} > 0$. First, suppose that $\underline{\theta}(\Phi^{sb}) = \underline{\theta}_{\Phi}^{sb}$, then (A15) rewrites as:

$$\frac{(1 - p)S_a}{Q_{\theta}(\underline{\theta}_{\Phi}^{sb}, \underline{\theta}_{\Phi}^{sb})} = \frac{1 - F(\underline{\theta}_{\Phi}^{sb})}{f(\underline{\theta}_{\Phi}^{sb})} S_p. \quad (\text{A17})$$

Substituting $\underline{\theta}(\Phi^{sb}) = \underline{\theta}_{\Phi}^{sb}$ into the first-order condition (26) one has $\underline{\theta}_{\Phi}^{sb} = 0$. Then **A7** implies that

(A17) cannot hold, and therefore $\underline{\theta}(\Phi^{sb}) \neq \underline{\theta}_{\Phi}^{sb}$. Second, showing that $\underline{\theta}(\Phi^{sb}) > \underline{\theta}_{\Phi}^{sb}$ follows from a revealed preferences argument. Suppose that there exists an equilibrium where only the boss self-reports, and denote by $\hat{\Phi}^{sb}$ the optimal amnesty such that $0 < \underline{\theta}(\hat{\Phi}^{sb}) < \hat{\theta}_{\Phi}^{sb}$. In such equilibrium there will be a subset of states where the trial takes place — i.e., for all $\theta \in [0, \underline{\theta}(\hat{\Phi}^{sb})$). But, for any given $\underline{\theta}(\hat{\Phi}^{sb})$, Proposition 2 implies that the Legislator can strictly reduce the crime rate by letting the agent talk in some states $\theta < \underline{\theta}(\hat{\Phi}^{sb})$ — i.e.,

$$\int_0^{\underline{\theta}(\hat{\Phi}^{sb})} (q(\theta) S_p - u_0) dF(\theta) < \max_{\underline{\theta}, s(\theta)} \left\{ \int_0^{\underline{\theta}} (q(\theta) S_p - u_0) dF(\theta) + \int_{\underline{\theta}}^{\underline{\theta}(\hat{\Phi}^{sb})} \left[Q(s(\theta), \theta) S_p - u_0 - RQ_{\theta}(s(\theta), \theta) \frac{F(\underline{\theta}(\hat{\Phi}^{sb})) - F(\theta)}{f(\theta)} \right] dF(\theta) \right\}.$$

It then follows that $\underline{\theta}(\Phi^{sb}) > \underline{\theta}_{\Phi}^{sb}$ and that (29) is a necessary condition to identify an internal optimum.

In order to complete the proof we must verify that there cannot be profitable deviations from the equilibrium outcome where the agent talks and is admitted into the program only if $\theta \in [\underline{\theta}^{sb}, \underline{\theta}(\Phi^{sb})$), while the boss self-reports only if $\theta \geq \underline{\theta}(\Phi^{sb})$ and in these states the agent is convicted with certainty.

Consider first the boss. Showing that he cannot gain by self-reporting for $\theta < \underline{\theta}(\Phi^{sb})$ is straightforward: it immediately follows from equation (28) and **A1-A2**. Next, suppose that he does not talk for $\theta > \underline{\theta}(\Phi^{sb})$, to show that this is indeed suboptimal we have verify that in this ‘off equilibrium’ path the following happens: (i) the agent cooperates and, (ii) his testimony is such that the boss’ deviation is not profitable. Consider then the allocation $\tilde{s}(\hat{\theta}) = \hat{\theta}$ and $\tilde{\phi} = \phi_{\Phi}^{sb}(\underline{\theta}(\Phi^{sb}))$ and suppose that it is incentive compatible — i.e., $\hat{\theta} = \theta$ for $\theta \geq \underline{\theta}(\Phi^{sb})$ (a conjecture that will be checked ex post). By construction, the boss will not find it profitable to deviate because under **A1** the following is true:

$$Q(\theta, \theta) S_p > (1 - \Phi^{sb}) S_p + \delta \quad \forall \theta > \underline{\theta}(\Phi^{sb}).$$

We can now show that $\tilde{s}(\hat{\theta}) = \hat{\theta}$ and $\tilde{\phi} = \phi_{\Phi}^{sb}(\underline{\theta}(\Phi^{sb}))$ is indeed incentive compatible for any $\theta > \underline{\theta}(\Phi^{sb})$ provided that the boss has (unexpectedly) not self-reported. To do so, we need to check that the agent cannot profitably deviate neither from mimicking a type $\hat{\theta} > \underline{\theta}(\Phi^{sb})$ nor a type $\hat{\theta} < \underline{\theta}(\Phi^{sb})$. Given the ‘off-equilibrium’ policy $(\tilde{s}(\hat{\theta}), \tilde{\phi})$, it is immediate to show that mimicking a type $\hat{\theta} > \underline{\theta}(\Phi^{sb})$ is not convenient because both the first- and second-order local incentive constraints are satisfied (which by standard arguments also implies that the global incentive constraint holds). Suppose now that the agent lies by claiming that $\hat{\theta} \leq \underline{\theta}(\Phi^{sb})$, his utility would then be:

$$u(\hat{\theta}, \theta) = -(1 - \phi_{\Phi}^{sb}(\hat{\theta})) S_a - (1 - Q(s_{\Phi}^{sb}(\hat{\theta}), \theta)) R, \quad (\text{A18})$$

implying that

$$\frac{\partial u(\hat{\theta}, \theta)}{\partial \hat{\theta}} = \dot{\phi}_{\Phi}^{sb}(\hat{\theta}) S_a + Q_s(s_{\Phi}^{sb}(\hat{\theta}), \theta) \dot{s}_{\Phi}^{sb}(\hat{\theta}) R.$$

Note that $Q_{s\theta}(\cdot) > 0$ and $\dot{s}_{\Phi}^{sb}(\hat{\theta}) > 0$ together with the local incentive constraint (5) yield:

$$\dot{\phi}_{\Phi}^{sb}(\hat{\theta}) S_a + Q_s(s_{\Phi}^{sb}(\hat{\theta}), \theta) \dot{s}_{\Phi}^{sb}(\hat{\theta}) R > \dot{\phi}_{\Phi}^{sb}(\hat{\theta}) S_a + Q_s(s_{\Phi}^{sb}(\hat{\theta}), \hat{\theta}) \dot{s}_{\Phi}^{sb}(\hat{\theta}) R = 0 \quad \forall \hat{\theta} \leq \underline{\theta}(\Phi^{sb}) < \theta.$$

Hence:

$$\frac{\partial u(\hat{\theta}, \theta)}{\partial \hat{\theta}} = \dot{\phi}_{\Phi}^{sb}(\hat{\theta})S_a + Q_s(s_{\Phi}^{sb}(\hat{\theta}), \theta)\dot{s}_{\Phi}^{sb}(\hat{\theta})R > 0 \quad \forall \hat{\theta} \leq \underline{\theta}(\Phi^{sb}) < \theta.$$

This implies that if the agent mimics at $\theta > \underline{\theta}(\Phi^{sb})$ by announcing $\hat{\theta} \leq \underline{\theta}(\Phi^{sb})$, he will always pretend to be in state $\underline{\theta}(\Phi^{sb})$ — i.e., where the information rent that he gets by reporting a $\theta' \leq \underline{\theta}(\Phi^{sb})$ is maximal. But then, he could do strictly better from telling the truth and obtain the allocation $\tilde{s}(\theta) = \theta$ and $\tilde{\phi} = \phi_{\Phi}^{sb}(\underline{\theta}(\Phi^{sb}))$. This can be easily verified by using equation (A18): in this case the agent's expected utility would be:

$$\tilde{u}(\theta) = -(1 - \phi_{\Phi}^{sb}(\underline{\theta}(\Phi^{sb})))S_a - (1 - Q(\theta, \theta))R,$$

which immediately yields:

$$\tilde{u}(\theta) > u(\underline{\theta}(\Phi^{sb}), \theta) = -(1 - \phi_{\Phi}^{sb}(\underline{\theta}(\Phi^{sb})))S_a - (1 - Q(\underline{\theta}(\Phi^{sb}), \theta))R,$$

since $\theta > \underline{\theta}(\Phi^{sb})$. It then follows that, given the policy described in the statement of the proposition, for $\theta > \underline{\theta}(\Phi^{sb})$ the agent truthfully reveals his type if his application to the program is accepted. Hence, the boss' expected sanction would be $Q(\theta, \theta)S_p$, which exceeds the cost of self-reporting $(1 - \Phi^{sb})S_p + \delta$ by (28) and **A1**.

We now show that there exist no other acceptance rules that maximize welfare. Suppose first that the Legislator rejects the agent's application when $\theta \in [\underline{\theta}^{sb}, \underline{\theta}(\Phi^{sb})]$. This is clearly suboptimal since, by Lemma 1, in these states the boss never self-reports. Second, suppose that for all $\theta \geq \underline{\theta}(\Phi^{sb})$ the Legislator rejects the boss' application and accepts the agents' one. But this would imply $\underline{\theta}(\Phi^{sb}) = \bar{\theta}$, which contradicts (A16). Finally, suppose that for $\theta \geq \underline{\theta}(\Phi^{sb})$ the Legislator also allows the agent to blow the whistle and accords leniency to both criminals. But, as seen in the proof of Proposition 9, this is never optimal: there is no reason to reward the agent for an information that is already supplied by the self-reporting boss.

Showing that the rationing and global incentive constraints hold for all types $\theta \in [\underline{\theta}^{sb}, \underline{\theta}(\Phi^{sb})]$ follows exactly the same steps as those developed in the proof of Proposition 2.

We can now show that $\underline{\theta}(\Phi^{sb}) < \underline{\theta}(\Phi^{fb})$, or equivalently $\Phi^{sb} > \Phi^{fb}$. The first-order conditions for Φ^{fb} and Φ^{sb} can be rewritten:

$$(1 - p)S_a = \frac{1 - F(\underline{\theta}(\Phi^{fb}))}{f(\underline{\theta}(\Phi^{fb}))} S_p Q_{\theta}(\underline{\theta}(\Phi^{fb}), \underline{\theta}(\Phi^{fb})), \quad (\text{A19})$$

and

$$(1 - p)S_a + R \int_{\underline{\theta}_{\Phi}^{sb}}^{\underline{\theta}(\Phi^{sb})} Q_{\theta}(s_{\Phi}^{sb}(\theta), \theta) d\theta = \frac{1 - F(\underline{\theta}(\Phi^{sb}))}{f(\underline{\theta}(\Phi^{sb}))} S_p Q_{\theta}(\underline{\theta}(\Phi^{sb}), \underline{\theta}(\Phi^{sb})), \quad (\text{A20})$$

respectively. Note that the left-hand side of (A20) is larger than the left-hand side of (A19) because $\underline{\theta}(\Phi^{sb}) > \underline{\theta}_{\Phi}^{sb}$ and $Q_{\theta}(\cdot) > 0$. Moreover, for any given Φ , the right-hand sides of the two equations are increasing in Φ under **A3** — i.e.,

$$\frac{\partial}{\partial \Phi} \left[\frac{1 - F(\underline{\theta}(\Phi))}{f(\underline{\theta}(\Phi))} Q_{\theta}(\underline{\theta}(\Phi), \underline{\theta}(\Phi)) \right] > 0.$$

Hence, $\underline{\theta}(\Phi^{sb}) < \underline{\theta}(\Phi^{fb})$ and $\Phi^{sb} > \Phi^{fb}$.

Finally, showing that $\phi_{\Phi}^{sb}(\theta) > \phi_{\Phi}^{fb}(\theta)$ for all $\theta \geq \underline{\theta}_{\Phi}^{sb}$ and that the first-order conditions (26)-(29) are

also sufficient for an optimum follows the same arguments used in the proof of Proposition 2. ■

Proof of Corollary 1. Showing that $s_{\Phi}^{sb}(\theta) > s^{sb}(\theta)$ for all $\theta \in [\underline{\theta}_{\Phi}^{sb}, \underline{\theta}(\Phi^{sb})]$ follows immediately from comparing equation (12) with (27) and $F(\underline{\theta}(\Phi^{sb})) < 1$ since $\underline{\theta}(\Phi^{sb}) < \bar{\theta}$. To show that $\underline{\theta}_{\Phi}^{sb} < \underline{\theta}^{sb}$ consider equations (11) and (26). Note that $\underline{\theta}_{\Phi}^{sb} = \underline{\theta}^{sb}$ for $\Phi^{sb} = 0$. Moreover, for any given Φ let

$$F(\underline{\theta}_{\Phi}^{sb}, \Phi) \equiv (Q(s_{\Phi}^{sb}(\underline{\theta}_{\Phi}^{sb}), \underline{\theta}_{\Phi}^{sb}) - q(\underline{\theta}_{\Phi}^{sb}))S_p - RQ_{\theta}(s_{\Phi}^{sb}(\underline{\theta}_{\Phi}^{sb}), \underline{\theta}_{\Phi}^{sb}) \frac{F(\underline{\theta}(\Phi)) - F(\underline{\theta}_{\Phi}^{sb})}{f(\underline{\theta}_{\Phi}^{sb})} = 0,$$

note that by the Envelope Theorem, (26) implies:

$$\frac{\partial \underline{\theta}_{\Phi}^{sb}}{\partial \Phi} = - \frac{F_{\Phi}(\underline{\theta}_{\Phi}^{sb}, \Phi)}{F_{\underline{\theta}}(\underline{\theta}_{\Phi}^{sb}, \Phi)} = \frac{1}{F_{\underline{\theta}}(\underline{\theta}_{\Phi}^{sb}, \Phi)} \frac{\partial \underline{\theta}(\Phi^{sb})}{\partial \Phi},$$

where $F_{\underline{\theta}}(\underline{\theta}_{\Phi}^{sb}, \Phi) > 0$ by concavity of the objective function with respect to $\underline{\theta}$, and $\partial \underline{\theta}(\Phi^{sb})/\partial \Phi < 0$ by (A14). Hence, $\partial \underline{\theta}_{\Phi}^{sb}/\partial \Phi < 0$, implying that $\underline{\theta}_{\Phi}^{sb} < \underline{\theta}^{sb}$. ■

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