Divide et Impera: Optimal Leniency Programs*

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Abstract

Leniency programs (or *policies*) reduce sanctions against cartel members that self-report to the Antitrust Authority. We focus on their ability to directly deter cartels and analogous criminal organizations by undermining internal trust, increasing individual incentives to "cheat" on partners. Optimally designed "courageous" leniency programs *reward* the first party that blows the whistle with the fines paid by all other parties, and with finitely high fines achieve the first best. "Moderate" leniency programs that only reduce or cancel sanctions, as implemented in reality, may also destabilize and deter cartels by (a) protecting agents that defect (and report) from fines; (b) protecting them from other agents' punishment; and (c) increasing the *riskiness* of taking part to a cartel.

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The son said to him, "Father, I have sinned against heaven and against you. I am no longer worthy to be called your son". But the father said to his servants, "Quick! Bring the best robe and put it on him. Put a ring on his finger and sandals on his feet. Bring the fattened calf and kill it. Let's have a feast and celebrate." (Luke 15, 21-23)

1 Introduction

Leniency programs or *policies* reduce sanctions against colluding firms that report information on their cartel to the Antitrust Authority. These schemes have attracted much attention in recent years thanks to the new *Corporate Leniency Policy* for Antitrust violations, introduced by the US Department of Justice (DoJ) in 1993 and widely regarded as a tremendous success.[1] Since its introduction an unprecedented number of cartels has been detected and successfully prosecuted, enormous fines have been levied against participants (up to US$ 500 millions), and several top executives from different countries have served jail sentences in the US.[2] This celebrated success led Australia, Canada, the European Union, France, Germany, New Zealand, the UK, Sweden and other countries to introduce analogous programs, and many more to discuss their possible introduction (OECD 2002, 2003).

Although breaking down adversary coalitions by playing members against each other is a consolidated practice since Julius Cesar – who named it *Divide et Impera* – we cannot be sure that current leniency policies are the success they are claimed to be. The optimistic view that the increase in convicted cartels reflects an increase in cartel deterrence is plausible, but the actual change in active cartels caused by the Corporate Leniency Policy cannot be observed, and in principle the observed increase in detected cartels could even be due to an increase in cartel activity. Even if we were sure that current leniency programs do increase cartel deterrence, we do not know whether differently designed ones would have done better. This calls for theoretical (and experimental!) analysis.

The issue is not only relevant to Antitrust policy. As an illegal activity involving many agents, cartels can be considered a form of *organized crime*, certainly not the most harmful. Long term corruption (where at least two parties are repeatedly involved, a briber and a bribee), collusion between agents and supervisors (e.g. auditors and management, or regulators and regulated firms), large scale frauds (including financial ones), mafia, terrorism and most kinds of illegal trade (in drugs, arms or people, where at least a buyer and a seller repeatedly interact) share with cartels a fundamental "governance problem": to curb internal moral hazard, prevent 'hold up' and ensure compliance with illegal agreements collaborating wrongdoers cannot rely on explicit contracts enforced by the legal system. This is why, as cartels, most other forms of organized crime take the form of long-term dynamic criminal *relationships,* where reputational considerations and implicit contracts can substitute for ex-

[1] Together with the companion Individual Leniency Policy. The DoJ introduced a leniency policy for cartels already in 1978, but the old policy was much less generous than the new one. As a result, very few firms applied for leniency before 1993.

[2] See Spratling (1998, 1999) and Hammond (2000, 2001) for overviews.

plicit contracting. The social costs of these activities to society are obviously very large. Understanding the optimal design of law enforcement policies against cartels also sheds light on how to fight these other forms of organized crime, and is therefore of primary importance.

Sustaining cooperation in illegal relationships between multiple wrongdoers requires a certain degree of trust, so one way prosecutors have traditionally fought organized crime is by shaping private incentives to play one party against the other. This is the idea behind leniency programs: ensuring that wrongdoers find themselves in a situation as close as possible to a Prisoner's Dilemma their long term relationship notwithstanding.[3] These policies have been used more or less explicitly to fight several forms of organized crime. Most notably, they have been extensively used in the US and Italy to fight Sicilian Mafia, and are routinely used (and misused) in the US to fight drug-dealing and related crimes.[4]

It is often argued that leniency for whistleblowers may directly deter organized crime by inducing undetected wrongdoers to spontaneously self-report and "turn in" their partners. The idea is of course undermining trust between wrongdoers with the increased risk that one of them unilaterally reports to enjoy the benefits of the leniency program (which are typically restricted to the first reporting party). Indeed, a crucial new feature of the Corporate Leniency Policy is its "Amnesty Program" – Section A – that "automatically" awards full immunity from sanctions to the first, and only the first cartel member that spontaneously reports information before an investigation is opened. According to DoJ officials, it is precisely this new feature that has led so many companies to come, and often rush forward with information on their cartel in the last years.[5] This view appears consistent with the exponential increase in reported cartels that took place in Europe since the Commission, in February 2002, revised its six years old Leniency Program and also started offering automatic immunity to the first member of a cartel that self-reports before an investigation is opened.[6]

[3] Agents involved in a cartel or in the mentioned forms of organized crime are in a Prisoner's Dilemma situation already without the leniency program, since each of them can "run away with the money". But typically the situation is repeated, and dynamic self-enforcing illegal agreements among wrongdoers can be sustained by reputational forces. What leniency programs can do is changing the payoffs in this dynamic game, so that the choice between colluding and defecting-and-reporting looks *again* similar to a that in a static Prisoner's Dilemma.

[4] The misuse occurs when prosecutors and courts rely exclusively (or mainly) upon a testimony obtained in exchange for leniency. A useful introduction to this incredible practice is at *http://www.pbs.org/wgbh/pages/frontline/shows/snitch/.* Throughout the paper we will assume that the party applying for leniency must report "hard information" against his partners to obtain it.

[5] According to Scott Hammond, Director of Criminal Enforcement of the DoJ Antitrust Division, about 50% of the leniency applications are now spontaneous reports falling within Section A of the Corporate Leniency Policy (personal communication). In his words, "over the last five years, the Amnesty Program has been responsible for detecting and prosecuting more antitrust violation than all of our [other investigating tools]" (2001). Similar statements can be found in Spratling (1998, 1999).

[6] In the year following the February 2002 revision more than twenty application for leniency were filed, most of which were immunity applications made spontaneously before any investigation was started (Van Barlingen, 2003). In contrast, in the six years between 1996 (when the first EC Leniency Program was introduced) and 2002 only 16 applications for leniency were filed, of which just three led to the granting of immunity. In 2004 DG Competition had to undertake an internal reorganization to handle all the cartel cases being reported.

This paper focuses precisely on this aspect of leniency programs: their ability to deter cartels by undermining trust with the increased incentives to spontaneously self-report to the Antitrust Authority.

We study a stylized dynamic model of self-enforcing collusive/criminal relationships embedded in a simple law enforcement environment à la Gary Becker (1968).[7] The model includes the possibility to offer reduced or negative fines (rewards financed by fines imposed on convicted wrongdoers) to agents that report "hard" information on their cartel.

First we determine the optimal law enforcement policy in the absence of leniency policies. We find that law enforcing agencies should then try commit not to target agents that unilaterally defect from collusive strategies, and make this policy public. The reason is close to the logic of leniency: if agents know that they will not be fined for their past wrongdoing if they defect from the collusive agreement, they are more prone to do it, which destabilizes cartels.

We then analyze how leniency programs affect the collusive game. When these programs are sufficiently generous, they can be exploited by agents who may agree to collude and report each period, enjoy leniency and avoid part or all fines. This increases the value of a collusive/criminal agreement and reduces deterrence. But when these programs are sufficiently generous, they also directly increase agents' incentive to unilaterally defect and report information. This increases the value of defecting, and deterrence. Taking these two effects into account we can characterize the optimal law enforcement policy with leniency.

We find that an optimal leniency policy is restricted to the first party that spontaneously reports. Allowing more agents to obtain leniency makes the program more easily exploitable (fewer agents must pay the full fine each period) and reduces the maximal reward that can be offered to the first agent that reports. The optimal policy also maximizes fines. High fines are valuable not only because they reduce the expected value of collusive-criminal relations, as in Becker (1968), but also because they allow to offer higher rewards to agents that blow the whistle by both financing the reward and preventing agents to exploit it. Unless fines are exogenously constrained to be very small, *the optimal policy offers the first reporting agent a reward equal to the sum of all fines paid by his former partners.* Large fines can finance a large reward for the first reporting agent, and a sufficiently large reward leads a rational agent to defect from any collusive/criminal agreement, report and cash the reward. When fines and rewards are sufficiently (but finitely) high, no agreement is therefore sustainable and the first best obtains (complete and costless deterrence).[8] We name "courageous" these "high powered" leniency policies offering rewards to the first reporting agent, as rewarding former wrongdoers is sometimes regarded as "immoral" (although the Bible suggests otherwise).

[7] A dynamic model is essential for a correct analysis of these issues, because criminal agreements like cartels are illegal and must therefore be sustained by repeated/dynamic interaction (credible threats). Law enforcement parameters interact in a complex way with dynamic incentives determining the amount of criminal cooperation sustainable in equilibrium. Only a dynamic model can correctly capture this crucial interaction.

[8] To our knowledge, it is the first time that the first best is achieved in a model of law enforcement à la Becker.

Since political and institutional constraints may prevent offering rewards, we go on to analyze constrained-optimal "moderate" leniency programs, where reduced fines are bounded to be non-negative (rewards are excluded). We identify three effects ensuring that moderate leniency programs restricted to the first, spontaneously reporting party may make collusive/criminal agreements harder to sustain.

The first is a *protection from fines* effect, present as long as the reduced fines of the moderate leniency program are below the expected fine of a defecting agent that does not report. By increasing the expected payoff of an agent that defects and reports above that of an agent that just defects, the moderate leniency program tightens wrongdoers' incentive constraints. The second is a *protection from punishment* effect, present when collusive/criminal agreements are sustained by two-phase, stick-and-carrot punishment strategies à la Dilip Abreu (1986) and repeat offenders are punished harder than first time ones. A report then raises future fines reducing expected profits from further collusion. This limits the costs agents are willing to incur in punishing defections in the first place.

The third and most important reason why even moderate leniency programs may have deterrence effects is that they can make participation to the illegal agreement more *risky.* We introduce *strategic risk* considerations in the spirit of John Harsanyi and Reinhardt Selten (1988) in a simplified version of the model. We show that even moderate leniency programs always strictly increase the riskiness of complying with a given collusive/criminal agreement. Moreover, we find that riskiness increases strictly more when eligibility to the program is restricted to the first reporting party, offering further support to DoJ officials' claim that the 'first comer rule' is crucial in generating breakdowns of trust in cartels and the consequent rushes to report.

The remainder of the paper is organized as follows. We start with a review of related work. Section 3 describes the model. Section 4 derives the optimal law enforcement policy in the absence of leniency programs. Section 5 analyzes how leniency programs affect the sustainability of collusive/criminal agreements in equilibrium, and characterizes the optimal law enforcement policy when rewards are feasible. Section 6 considers constrained-optimal policies where rewards are not allowed. Section 7 characterizes the effects of leniency when agents care about strategic risk. Section 8 discusses robustness issues and concludes. All proofs are in the Appendix.

2 Literature review

Despite the prominence of the Prisoner's Dilemma game in economics and the importance of organized crime in society, until very recently there was no systematic economic investigation of the effects of leniency programs on long-term, dynamic forms of organized crime like cartels. The earliest analysis we are aware of that is somewhat close in spirit to our work is Fred Koffman and Jacques Lawarrée (1996), where in a static principal-supervisor-agent model à la Jean Tirole (1986) it is proposed to bring in a second supervisor and structure the supervisors' incentives as a Prisoner's Dilemma to prevent supervisor-agent collusion.

The first in depth economic analysis explicitly addressing the dynamic effects of leniency policies on long term cartels is by Massimo Motta and Michele Polo (2003). Our approaches are complementary. We look for the optimal design of law enforcement policies with leniency programs in a model of crime deterrence à la Becker (1968), where detection and conviction are identified with a single probability and the cost of enforcement is a choice variable for the policy maker. In this sense, we are mainly focusing on the optimal design and deterrence effects of Section A of the US Corporate Leniency Policy. Motta and Polo's model is instead in the spirit of the plea bargaining literature, with an exogenous cost of law enforcement and with detection leading to conviction only with some probability. Their model is designed to answer the question whether firms that report information when being already under investigation should also be eligible to leniency. Their main focus, therefore, is on the value of Section B of the Corporate Leniency Policy, and their central result is that it may indeed be optimal to offer leniency to firms that report when under investigation, as it may indirectly increase deterrence by making prosecution more effective, a result on which we fully agree.

Besides in focus, our paper and Motta and Polo's differ crucially in both assumptions and results. Their paper do not consider rewards nor strategic risk; assumes that firms sustain collusive agreements with grim trigger strategies (we allow for other punishment strategies), and that a defecting firm cannot be convicted for having taken part to a cartel, nor can report information on former partners (we take into account both these possibilities). Under these more restrictive assumptions – required to solve their richer model – the "protection from fines" and the "protection from punishment" effects do not emerge, and strategic risk is not considered, a moderate leniency program appears unable to induce any agent to spontaneously self-report. This leads to their conclusions that to have any effect a leniency program must be open to firms under investigation, that the same lenient treatment should be offered to all firms independent of who reports first (under their assumptions removing the "first comer rule" – the benefit of being the first firm to report – has no cost), and that leniency programs are second-best (i.e. if the Antitrust Authority has sufficient resources to deter cartels through fines and inspections it should not introduce any leniency program).

These conclusions conflict directly with our results that an optimally designed leniency program can deliver the first best, that it is always optimal to have a leniency program even if moderate, and that an optimal leniency program restricts eligibility to the best treatment (rewards or full amnesty) to the first firm that reports, as in reality.

Many other papers have been written on the subject after Motta and Polo's (1999, 2003) and the present paper (Spagnolo 2000a) were circulated, and we can only mention few of them here (see Rey 2003 and Spagnolo 2005 for surveys of this growing literature).

An important closely related paper is Cecile Aubert, William Kovacic and Patrick Rey (2004). Developed independently and almost simultaneously to our, this paper also considers rewards in Antitrust enforcement in a simpler model that allows to focus on important issues complementary to those we discuss. They consider the costs and benefits of creating an agency problem between firms and their individual employees by allowing the latter to directly cash rewards when they blow the whistle and report their own firm's collusive behavior. They note, among other things, that many inefficiencies attributed to rewarding whistleblowers, such as forcing firms to reduce employees' rate of turnover or to adopt a more "innocent" internal image, are additional costs of collusion that increase cartel deterrence. They also discuss several potential explanations for the puzzling fact that firms keep "hard" information on their cartel at the risk of being detected by competition authorities, including that firms may need instruments to obtain leniency in case the cartel breaks down, and to persuade partners that they did not "cheat" in presence of uncertainty and imperfect information.

Paolo Buccirossi and Spagnolo (2001) and Spagnolo (2000b) highlight in different contexts another reason why wrongdoers/colluding firms may choose to keep hard evidence linked to a potential drawback of moderate leniency programs. When leniency programs are present, the threat of reporting the cartel-organized crime to the law enforcement agency in case of a defection becomes a credible one, and can be used to enforce collusion in *occasional* market/criminal interactions, where no illegal agreement could be sustained in the absence of the law. Buccirossi and Spagnolo (2001) show that this potential crime-enhancing effect of prohibitions and leniency is stronger for sequential illegal transactions like corruption, and that the optimal rewards proposed here would also remove this paradoxical effect.

Cristopher Ellis and Wesley Wilson (2002) developed a model of the current leniency programs that offers a new perspective. They show that a moderate leniency program may induce firms to report information in order to damage competitors and obtain a strategic advantage. Their result, together with our, helps explain the rush of cartel breakdowns with spontaneous reports that has taken place in the US these last years. These authors also find that leniency programs may end up having the perverse effect of stabilizing those cartels that they could not deter, reinforcing results in Buccirossi and Spagnolo (2001) and Spagnolo (2000b).

A recent paper by Josè Apesteguja, Martin Duwfemberg and Reinhard Selten (2004) compares experimentally the performance of moderate leniency and rewards in a one-shot Bertrand setting analogous to Spagnolo (2000b). The experiment confirms that subjects do understand and make use of reporting as a threat to enforce collusion in *occasional* interactions. The authors conclude that moderate leniency appears to work better than rewards as a cartel deterrence mechanism, although for unclear reasons. This study is a very important first step in the experimental direction, but its results are hard to interpret and relate to this paper and to real world competition policy against long term cartels because of the somewhat unrealistic set up (one-shot game, Bertrand oligopoly, extreme rules for setting fines) and because subjects are not allowed to learn the game by playing it repeatedly (so that mistakes may have affected outcomes, as happened in early experimental studies of public good contribution). More experimental work, therefore, appears highly needed.

Finally, our paper is related to the literature on optimal law enforcement stemming from Becker (1968), and in particular on recent work on self-reporting. Focusing on individual wrongdoers committing isolated crimes, Louis Kaplow and Steven Shavell (1994) showed how reducing sanctions against wrongdoers that spontaneously self-report lowers law enforcement costs and increases welfare by reducing the number of wrongdoers to be detected and the risk born by risk-averse wrongdoers. Arun Malik (1993) discusses the role of self-reporting in reducing auditing costs in environmental regulation. And Robert Innes (1999) highlights the value of the early remediation of damages that self-reporting allows for. These papers recognize important benefits that a lenient treatment of self-reporting wrongdoers bring about, but do not deal with its ability to undermine trust in cartels and other long term self-enforcing illegal relationships by eliciting information from individual members, the object of this paper.[9]

3 Basic model

Let there be an economy with many oligopolistic industries – or a society with many potential criminal organizations – each of which can be represented by a discounted infinitely repeated (oligopolistic or criminal) game between a number of risk neutral agents. Let there also be a benevolent Legislator who – having forbidden welfare–reducing collusive/criminal behavior – sets the parameters of the law enforcement policy. Because our paper is normative, we follow the literature in assuming that the Legislator sets and commits to law enforcement policy parameters first. Then, having observed those policy choices, agents interact in the oligopolistic (or criminal) supergame.

TIMING

- Step 1: The Legislator commits to law enforcement policy parameters
- Step 2: Agents observe the policy parameters and start interacting

3.1 Cartels (organized crime)

For the sake of crispness in the remainder of the paper we will phrase our discussion in terms of collusive agreements between oligopolistic firms. However, the reader should keep in mind that all reasoning and results directly apply to the analogous forms of organized crime discussed in the introduction.

We focus on industries where the exercise of collusive market power generates deadweight welfare losses that dominate any potential dynamic gain. A representative industry consists of $N \geq 2$ symmetric, infinitely lived and risk neutral firms interacting repeatedly in an oligopolistic market stage game in the infinite, discrete time denoted by $t = 1, 2...$ We assume that agents/firms discount future payoffs through a common factor δ, with $0 < \delta < 1$, and that the market stage game has a unique pure strategy Nash equilibrium, with π^n denoting agents' payoff at this equilibrium.

[9] Fees and Walzl (2004) apply ideas in Motta and Polo (2003) and (the previous version of) this paper to Kaplow and Shavell's (1994) self-reporting model, but maintain their model static, assuming agents' ability to cooperate/collude rather than deriving it. Obviously agents' ability to cooperate/collude depends crucially on future payoffs, and through these on the law enforcement parameters. Simplified static analyses of collusion/organized crime such as Fees and Walzl (2004) disregard this crucial dynamic link, so we can't avoid regarding them as incorrect.

In the absence of law enforcement, firms can sustain a stationary collusive agreement in subgame perfect Nash equilibrium if the value of sticking to the agreement – the discounted sum of expected payoffs from respecting the agreement V^c– exceeds the value V^d of optimally unilaterally defecting and then being subject to the punishment phase that disciplines the agreement. The correspondent algebraic condition for a representative firm is

$$V^c = \frac{\pi^c}{1-\delta} > \pi^d + \delta V^p = V^d,$$

or, normalized by $(1-\delta)$,

$$\pi^c > (1-\delta)\pi^d + \delta v^p, \tag{1}$$

where π^c denotes a firm's static payoff from sticking to the collusive agreement; π^d that from unilaterally deviating from the agreement and choosing the static best response (of course $\pi^d > \pi^c > \pi^n$); V^p denotes the discounted sum of payoffs expected at the beginning of the punishment phase following a firm's unilateral defection; and v^p denotes the time-average payoff a firm that defected unilaterally earns after the defection, so that $v^p = (1-\delta)V^p$ (the superscript p is for "punished"). Of course it must be $v^p < \pi^c < \pi^d$, since to enforce collusion cartel members must penalize defecting ones in one way or another. Finally, π^b will denote the payoff a colluding firm obtains when one of its partners defects unilaterally, where $\pi^b \leq \pi^n < \pi^c < \pi^d$.[10]

We will try keep as general as possible by not specifying particular punishment strategies. Specific punishment strategies will be discussed when they are important for a given result. The focus will be on punishments that are optimal in the sense of Abreu (1996, 1998) for some specifications of the underlying stage game.

3.2 Information

Detected cartels showed that collusive agreements are often very complex, need to be administered and monitored, and induce members to communicate and meet regularly, to exchange documents and e-mail messages, and to produce other kind of hard evidence on the cartel that expose them to the risk of conviction.[11] Consequently, we assume that each period a cartel is active, a piece of "hard" evidence is generated, and that this is independent of

[10] To translate the results we obtain for cartels into correspondent results for analogous forms of organized crime, it is sufficient to reinterpret variables. For example, for corruption, the number of players N will typically be two, say a firm and a bureaucrat; collusive profits π^c can be reinterpreted as the gains from a completed corrupt transaction; profits from a unilateral deviation π^d can be reinterpreted as a party's gains from "holding up" the other in the corrupt exchange; and so on.

[11] Michihiro Kandori and Hitoshi Matsushima (1998), and Olivier Compte (1998) elegantly show that communication may indeed be necessary to support collusive outcomes once one allows for asymmetric information between firms. The DoJ, on the other hand, has a fantastic video (recorded by a leniency applicant) of some meetings of an international cartel showing that managers bring along documents on past sales and profits, compare them with documents on the agreed quotas, and discuss possible compensations/adjustments to be implemented in the future (and joke about the absence of buyers and DoJ representatives at their meeting, leaving empty chairs for them at their table and singing childish songs on how nice it is to exploit buyers!).

whether a unilateral defection from collusive strategies takes place.[12] We can think of each stage game of the dynamic game as being composed of two substages: in the first cartel members communicate – e.g. to confirm/update future collusive strategies, exchange and discuss information on market outcomes, etc. – thereby generating hard information; in the second they set the relevant market variables and choose whether to report information to the Antitrust Authority.[13]

For simplicity, we assume that each cartel member possesses the hard evidence produced by the cartel and can costlessly transmit it to third parties if he wishes; that if an agent reports the hard evidence it possesses to the law enforcing agency the cartel is convicted with probability one; and that there is "full information decay" in the sense that all hard information on a cartel active at time t vanishes at time $t+1$. It will become clear that the qualitative results of the paper do not depend on any of these simplifying assumptions.

Finally, we limit attention to the case of public information revelation by assuming that when a firm reports its hard information to the law enforcing agency, its report becomes public information at the end of the period (to obtain the conviction of a cartel prosecutors must usually disclose available information and its sources to courts and defendants).[14]

3.3 Law enforcement

The Legislator can set the following parameters of the law enforcement policy, within limits dependant on exogenous (e.g. political) factors:

1. A monetary fine F, with $F \in [\underline{F}, \overline{F}]$, that a colluding firm has to pay if convicted for the first time.[15]

2. A reduced fine RF ("reward" when $RF < 0$), with $RF \in [\underline{RF}, F]$, that a cartel member can pay/cash instead of F if – when it is not under investigation – he spontaneously reveals information allowing to convict his partners.

3. Per-period probabilities of conviction:

   α, by which cartel members are discovered and convicted in a period in which everybody conforms to agreed collusive strategies;[16]

[12] As mentioned in the introduction, Aubert et al. (2004) discuss a number of possible explanatons why cartel members produce and store so much hard evidence on the existence and functioning of the cartel, esposing them to risk of being convicted. A previous version of this paper assumed that evidence is produced only if no defection occurs, as in Motta and Polo (2003). The current assumption is more realistic, since in reality undercutting ones' cartel is no guarantee not be convicted for past collusive activities, and allows us to model the effects of leniency programs on the "riskiness" of collusion. If a cartel produces no hard evidence whatsoever, on the other hand, there is no way to convict its members unless each of them pleads guilty.

[13] This two stage timing for the stage game is suggested in Rey (2003), and reflects well the behavior of real world cartels whose members meet regularly to monitor and update their agreement.

[14] The case of secret reports is considered in Rey (2003).

[15] Higher fines for repeat offenders are considered in Section 6.2, where we deal with the 'protection from punishment' effect.

[16] Kaplow and Shavell (1994) and Motta and Polo (2003) note, respectively, that for a given budget allocated

γ, by which a unilaterally defecting cartel member is convicted;

$\beta = \gamma + \eta$, with $\eta \geq 0$, by which a cartel member that conforms to agreed collusive strategies is convicted in a period when another member unilaterally defects.[17]

We focus on realistic parameter configurations by assuming $\alpha, \beta, \gamma < \frac{1}{2}$.[18] In the tradition of Becker (1968), we also assume that administering fines is costless, so that these can be regarded as welfare-neutral transfers, but that increasing each of the conviction probabilities is costly. We let $c_k(k)$, with $k \in \{\alpha, \beta, \gamma\}$, denote the (social) cost functions of implementing such probabilities, and assume $c_k(0) = 0$, $c'_k(k) \geq 0$, $c''_k(.) > 0$ and, to simplify some statements, $c'_k(0) = 0$.

As for rewards (negative RF), were they financed through taxation it would of course be reasonable to assume them costly to administer. However, we can restrict focus to *self-financing* leniency programs where rewards (if any) are financed by the fines levied on the same cartel, as otherwise any group of agents would find it profitable to pretend colluding just to self-report and cash the rewards.

Definition 1 *A leniency program is* self-financing *when the sum of rewards it pays to reporting agents (if any) is weakly smaller than the sum of the fines paid by other agents involved in the reported crime; i.e. when* $\sum RF \leq \sum F$.

Therefore, as positive fines, rewards will also be assumed costless to administer. Adding other (e.g. moral) costs of rewarding a wrongdoer that reports would complicate exposition, reduce the set of parameter configurations where a reward is optimal, but leave qualitative conclusions unchanged. It will also become clear that the basic framework sketched in this section can be complicated in many ways without qualitatively affecting results.[19]

4 Optimal law enforcement without leniency

Consider our representative industry when no leniency program is present, so that $RF = F$.

to antitrust enforcement the introduction of leniency may increase the probabilities of conviction by reducing the number of potential wrongdoers that need be inspected, and freeing resources for inspections by making prosecution more effective. On the other hand, when leniency leads many cartel members to self-report, the Antitrust Authority may become so busy prosecuting reported cartels that meanwhile the probability that non-reported cartels are detected may fall substantially (this is likely to have happened at the EC after the 2002 improvement of the leniency program). Taking these indirect effects into account would not affect our qualitative results, so we neglect them for the sake of crispness.

[17] The probability of conviction may differ after a defection, for example, because the defection may alert the Antitrust Authority or buyers of the possible presence of a cartel; it may differ across defecting and non defecting cartel members, for example, because it may be harder to prove the collusive conduct for a firm that just undercut the cartel.

[18] Available estimates of the probability that a cartel is detected at all in its lifetime are, for the US, below 0.2 (Bryant and Eckard, 1991).

[19] For example, non-monetary and fit-the-crime sanctions can easily be accommodated by the model, without substantial changes in results.

Value of colluding. Let V^{cr} denote the discounted payoff expected by a member of a convicted cartel who did not defect the period after being convicted, and v^{cr} the correspondent time-average payoff, with $V^{cr}(1-\delta) = v^{cr}$ (the superscript c is for "cooperator" and r for "repeated"). Of course v^{cr} is a function of firms' strategies and of the legal system. By sticking to agreed collusive strategies each firm expects the profit stream

$$\alpha(\pi^c - F + \frac{\delta v^{cr}}{1-\delta}) + (1-\alpha)\pi^c + (1-\alpha)\delta\left[\alpha(\pi^c - F + \frac{\delta v^{cr}}{1-\delta}) + (1-\alpha)\pi^c\right] + (1-\alpha)^2\delta^2[...,$$

so that – given that our stationary specification implies $V^c = V^{cr}$ – the value of the strategy "stick to the collusive agreement" is

$$V^c = \frac{\pi^c + \alpha(\frac{\delta v^{cr}}{1-\delta} - F)}{1-(1-\alpha)\delta} = \frac{\pi^c - \alpha F + \alpha\delta V^{cr}}{1-(1-\alpha)\delta} = \frac{\pi^c - \alpha F}{1-\delta},$$

which is decreasing in α and F.

Value of defecting. Discounted expected payoffs from defecting depend on the probability γ that the defecting firm is itself convicted. The value of defecting from collusive strategies is

$$V^d = \pi^d - \gamma F + \frac{\delta v^p}{1-\delta}.$$

Firms can therefore sustain the collusive agreement in subgame perfect Nash equilibrium if

$$V^c = \frac{\pi^c + \alpha F}{1-\delta} > \pi^d - \gamma F + \frac{\delta v^p}{1-\delta} = V^d. \tag{2}$$

Studying condition (2) leads to the first, benchmark result.

Proposition 1 *Absent leniency programs (i.e. with $RF = F$) the ex ante optimal fine is $F^* = \overline{F}$ if $\gamma < \frac{\alpha}{1-\delta} + \frac{\delta}{1-\delta}\frac{\partial v^p}{\partial F}$, and $F^* = 0$ otherwise;*[20] *the optimal law enforcement policy sets therefore $\gamma = 0$ and $F^* = \overline{F}$.*

Contrary to what happens in most standard law enforcement models, here increasing fines increases deterrence only as long as the probability γ of being convicted when defecting is sufficiently small relative to the probability α of being convicted while colluding. If instead a unilateral defection substantially increases the probability to be caught by the law enforcing agency, say because the defection reveals/signals the existence of a cartel and the Antitrust Authority treats defecting and non-defecting members of the cartel equally, a Becker-like result does not obtain: then an increase in fines deters *defections* from a cartel, rather than

[20] Note that with optimal punishments $\frac{\partial v^p}{\partial F}, \frac{\partial v^p}{\partial \alpha} \geq 0$. If collusion is supported by grim trigger strategies, e.g. because the underlying oligopoly game is à la Bertrand, then obviously $v^p = \pi^n (= 0)$ and $\frac{\partial v^p}{\partial F}, \frac{\partial v^p}{\partial \alpha} = 0$. When collusion is supported by two-phase "stick-and-carrot" punishments à la Abreu (1986), e.g. because the stage game is a Cournot oligopoly, it is either $\frac{\partial v^p}{\partial F}, \frac{\partial v^p}{\partial \alpha} = 0$, or $\frac{\partial v^p}{\partial F}, \frac{\partial v^p}{\partial \alpha} > 0$ because higher expected fines reduce future expected collusive profits (the carrot), tightens the no-defection constraint for the punishment phase, and may therefore require a parallel reduction in the strength of the "stick" to maintain subgame perfection.

the cartel itself.[21] Since increasing γ is costly and stabilizes cartels by discouraging defections, the optimal policy is to set $\gamma = 0$. And when γ is optimally set at zero Becker's (1968) logic applies and fines should then be maximal.

To better focus on the effects of the Leniency Program, in the remainder of the paper we restrict attention to the case $\gamma < \alpha$ and assume that the Legislator optimally sets $F = F^*$ (the optimality of this choice in this model is not affected by changes in RF).

5 Optimal leniency programs

With a leniency program in place agents may find it convenient to report information on the cartel, and this may change both the value of colluding V^c and that of defecting V^d. To characterize the optimal program we must understand how leniency affects V^c and V^d.

5.1 The effects of leniency

Exploitable leniency programs. Consider first the effects of a leniency program on the value of colluding. The value V^c may change because when the leniency program is sufficiently generous, colluding agents may find it convenient to consensually report their collusive behavior each period, to avoid facing the risk of being detected and fined by the law enforcing agency. When this is the case we will say that the leniency program is "exploitable", in the sense that agents can use it to reduce the expected cost of misbehavior. Let $V^{c\prime}$ denote the value of following the strategy profile that prescribes firms to collude and report their collusive agreement in each period.

Definition 2 *A leniency program is "exploitable" if it allows firms to increase the value of a collusive agreement by reporting it to the law enforcing agency (when $V^{c\prime} > V^c$).*

We assume that when the leniency program restricts eligibility to the first reporting firm only and agents agree to collude and report, either they report simultaneously – so that the reduced fine is allocated randomly – or they take turns to report and each period reallocate the difference between reduced and full fine among cartel members. Under either assumption, when firms agree to both collude and report, a firm's expected fine in each period is $\frac{(N-1)F+RF}{N}$.

Clearly, firms will choose to collude and report only when the leniency program is exploitable, so that $V^{c\prime} > V^c$. Since colluding agents can always choose not to report, the value of colluding cannot decrease with the introduction of a leniency program, it will be $\max\{V^c, V^{c\prime}\}$. It remains to be checked under which circumstances it is $V^{c\prime} > V^c$, so that the leniency program can be exploited. The following lemma characterizes such circumstances.

[21] The optimal policy would then require the law enforcement agency to avoid prosecuting cartel members who unilaterally defected from collusive strategies even if they did not self-report, offering an implicit form of leniency, and should make this policy of public domain. Joe Harrington (2003) obtains the related result that an Antitrust Authority using price wars as signals of the presence of a cartel may end up stabilizing collusion by increasing the strength of the punishment phase that disciplines defections with higher expected fines.

Lemma 1 *If all reporting agents are eligible to leniency, then the leniency program is exploitable if* $RF < \alpha F$*. If only the first reporting agent is eligible to leniency, then the leniency program is exploitable if* $RF < \alpha F - (N-1)(1-\alpha)F$*.*

Restricting eligibility to the first firm that reports reduces the set of exploitable leniency programs. This is of course the case because restricting eligibility implies that each time firms collude and report, all but one firms must pay the full fine. In the relevant parameter range ($\alpha < \frac{1}{2}$) restricting eligibility allows to reward reporting agents – the more generously the smaller α and the larger N – without making the program exploitable. On the contrary, unrestricted programs become exploitable already when the reduced fine equals or falls below the expected fine.

Effective leniency programs. Let $V^{d\prime}$ denote the value of defecting and simultaneously reporting information to the law enforcing agency. The natural assumption we adopt here is that if an agent decides to defect unilaterally from the agreed collusive strategies, he will be able to report before other firms, as even when collusive strategies prescribe firms to simultaneously report along the equilibrium path, a defecting agents can always slightly anticipate the time of his report relative to the agreed one.

The value of defecting cannot decrease with the introduction of the leniency program, it will be $\max\left\{V^d, V^{d\prime}\right\}$ since when $V^{d\prime} < V^d$ a defecting agent can always choose not to report. And of course as long as $V^{d\prime} < V^d$ the leniency program cannot be "effective" in terms of increasing agents' temptation to unilaterally defect and report.

Definition 3 *A leniency program is "effective" when it allows a firm that unilaterally defects from a collusive agreement to increase its payoff by also reporting information (when* $V^{d\prime} > V^d$*).*

The next lemma characterizes the circumstances under which the value of defecting increases with the introduction of the leniency program.

Lemma 2 *Independent of how many firms are eligible, the leniency program is effective if* $RF < \gamma F$*.*

The Lemma identifies a first way in which the leniency program can be effective in deterring cartels by increasing the value of defecting from an illegal agreement: protecting an agent that defects and reports from the expected fine γF he would otherwise face when defecting, replacing it with the reduced fine/reward RF. We name this *protection from fines* effect.

5.2 Globally optimal leniency programs

We can now proceed to characterize optimal leniency programs. Unconstrained optimal programs can be labelled "courageous" because it turns out that they prescribe that a substantial reward should be paid to the first agent that reports information to the law enforcing agency. In contrast, leniency programs implemented in reality are often "moderate", in the sense that they only reduce, or at best cancel sanctions for reporting firms. Such constrained-optimal moderate programs will be discussed in Section 6.

5.2.1 Optimal eligibility

Given other parameters of the law enforcement policy, an optimal leniency program trades off the costs it implies, if any, with the benefits of making the incentive compatibility conditions

$$\max\left\{V^c, V^{c\prime}\right\} > \max\left\{V^d, V^{d\prime}\right\} \tag{IC}$$

more stringent. Lemma 1 showed that restricting eligibility to the first firm that reports reduces the set of 'exploitable' leniency programs, enlarging the set of fine discounts/rewards that can be awarded without increasing the value of colluding. On the other hand, from Lemma 2 we know that the attractiveness of defecting and reporting is independent of the eligibility criteria, it only depends on the size of the fine discount/reward. This immediately implies the following.

Proposition 2 *An optimal leniency program is restricted to the first reporting agent.*

This appears consistent with how real world leniency programs are designed, i.e. with a large difference between the amount of leniency obtainable by the first reporting party (automatic complete amnesty) and that available to further reporting parties (discretional, partial reductions of sanctions).[22]

There is a further reason to restrict eligibility to amnesty to the first reporting party, not yet captured by our model but often stressed by DoJ officials, who see it as crucial to the effectiveness of the program. In reality, the first comer restriction appears to generate "races to report" caused by the "fear to arrive second". Were the second, third or forth reporting firms eligible to the same treatment as the first one such races would arguably not occur. Then firms could safely adopt a 'wait and see' strategy ("do not report first, be ready to report if somebody else does it"). We will try to capture this effect in Section 7, where we introduce strategic risk considerations.

Since we are interested in optimal leniency programs, the remainder of the paper will focus on programs restricted to the first reporting party (unless otherwise specified).

5.2.2 Optimal fine reductions/rewards

Assuming that when agents are indifferent between reporting and not reporting they choose to report, one can state the following.

Proposition 3 *The optimal leniency program (is restricted to the first reporting party and) has*

$$\begin{cases} RF^* = \alpha F - (N-1)(1-\alpha)F & \text{when} \quad F > \pi^c - v^p - \frac{\pi^d - \pi^c}{N-1}, \\ RF^* = \underline{RF} = -(N-1)F & \text{otherwise.} \end{cases}$$

[22] A smaller fine discount for the second reporting firm would become optimal in our model if we relaxed the (standard) assumption that if a firm reports the cartel is convicted with probability one, and assumed that a second report would increase the probability of conviction. Such an extension, however, would increase complexity and length of the paper without affecting any of its central results, so it is left to future work.

Note that in both cases the optimal leniency program establishes a *positive reward* for the first firm that reports information on its cartel. The intuition is of course that rewards improve the effectivity of leniency programs and cartel deterrence by increasing agents' gains from defecting from the collusive agreement and reporting it to the law enforcing agency (the right hand side of condition IC). Too high rewards, though, may make the program exploitable, hence the optimal reward may be smaller than the level at which the self-financing constraint binds. This is what happens as long as fines are sufficiently large. Then the optimal reward is the minimum one that leaves colluding firms indifferent between reporting and not reporting ($V^{c\prime} = V^c$; firms then report by our tie-breaking assumption). It is not optimal to increase the reward further because it would increase the program's exploitability ($V^{c\prime}$) faster than its effectivity ($V^{d\prime}$), thereby reducing deterrence. When fines are smaller, instead, increasing the reward above (decreasing RF below) the level where the program becomes exploitable increases deterrence, as the increase in effectivity dominates on the increase in exploitability, and it is optimal to set the reward maximal.

A second important thing to note is that in the first case, where fines are not too small, the optimal reward is decreasing in the detection probability α. This means that in the optimal mechanism *investigations and rewards are substitute law enforcement instruments*, even if they are not "exogenously" so because of a common budget constraint. When α is large, the optimal reward must be small because a high probability of paying fines when not reporting makes even moderate rewards for reporting attractive and leniency programs exploitable. The optimal self-financing reward is instead in all cases increasing in fines, so that *fines and rewards are complement instruments.* Independent of the inspection probability and of the complementarity induced by the budget/self-financing constraint, fines and rewards are complements because the first allow to award larger rewards without making the leniency program exploitable.

5.2.3 Optimal law enforcement: achieving the first best

Since investigations and rewards are substitutes, investigations cost $c_\alpha(\alpha)$, and self-financing rewards are costless, an optimal law enforcement policy should rely as much as possible on self-financing rewards. This simple reasoning leads to the following.

Proposition 4 *There exists a finite level of fines F' such that when $\overline{F} \geq F'$ the optimal law enforcement policy implements the* first best *– complete and costless deterrence – with $\gamma = \beta = \alpha = 0$, $F' \leq F \leq \overline{F}$, and $-(N-1)F \leq RF \leq -(N-1)F'$.*

The result tells us that, in contrast to what happen in Becker (1968) and in most of its extensions, here there is a finite level of fines that allows to completely deter collusion at no cost (in terms of inspection probability).[23] This is done by setting the reward for the

[23] Of course there will be costs linked to the court system, who has to evaluate/verify the information reported. These verification costs are usually disregarded in the law and economics literature stemming from Becker (1968), they are considered unavoidable. These costs would be present with and without a leniency program.

first reporting agent equal to the sum of the fines paid by his former partners, interrupting all forms of costly investigations and laying back on the chair waiting for wrongdoers to come forward with information. The combination of sufficiently high fines and high powered leniency programs make the public enforcement of law – the active investigation of organized crime – redundant, and actually suboptimal.

To our knowledge, this is the first time that the first best is achieved in a law enforcement model à la Becker (1968). Most previous work on optimal law enforcement focuses on individual crimes – where nobody has freely available information on the crime besides the individual criminals themselves – and shares the property of Becker's original model where even infinitely high fines cannot achieve the first best. A strictly positive probability of detection is necessary for law enforcement to have any effect, and the investigation costs that generate such positive probability are a deadweight loss that keeps society away from the first best.

6 Constrained-optimal "moderate" leniency programs

Exogenous political and institutional factors may constrain the design of the law enforcement policy. The most obvious way in which the design may be constrained is in the size of fines and of fine discounts/rewards. In this section we consider the optimal design of the law enforcement policy when institutional restrictions on the size of fines and of fine discounts/rewards are binding.

6.1 Constraints on fines and rewards

Constraints on fines. When exogenous factors constrain fines to be smaller than the level that leads to the first best ($\overline{F} < F'$), the second best law enforcement policy implies positive investigation costs and may imply a non maximal reward. The next proposition characterizes the second best law enforcement policy when the upper bound on fines is binding.

Proposition 5 *When the first best cannot be achieved because of a too low upper bound on fines ($\overline{F} < F'$), the optimal law enforcing policy has $\gamma = 0$, $F = \overline{F}$, $RF = RF^*$, where RF^* is defined in Proposition 3, and:*

1. *$\alpha > 0$ and such that $c'_\alpha(\alpha)$ equals the marginal social benefit of deterrence, when $F > \pi^c - \pi^n - \frac{\pi^d - \pi^c}{N-1}$;*

2. *$\alpha = 0$, when $F < \pi^c - v^p - \frac{\pi^d - \pi^c}{N-1}$.*

The proposition tells us that when maximal fines are too small to achieve the first best through self-financing rewards, it may be optimal to couple rewards with active investigations. Note that in the first case – where fines are not too small – investigations and rewards are substitute instruments, so that since the second best implies a positive α, it also implies less than maximal rewards.

Constraints on rewards. Offering rewards to wrongdoers that cooperate with prosecutors against their former partners is a consolidated practice in the US (see the Introduction). However, most *codified* leniency programs we are aware of are "moderate", in the sense that they do not explicitly allow to reward a wrongdoer that reports information and cooperates with the law enforcing agency.[24] They only allow to reduce, or at best cancel sanctions against agents that spontaneously self-report. For this reason, in this section we consider the optimal design of moderate leniency programs, constrained to non-negative reduced sanctions for wrongdoers who self report (the optimization is constrained by $RF \geq \underline{RF} = 0$); and in the next section we consider their deterrence effects.

The following proposition characterizes the optimal moderate leniency programs and the correspondent optimal law enforcement policy.

Proposition 6 *Suppose leniency programs are constrained to be moderate ($\underline{RF} = 0$). Then:*

1. *The constrained-optimal leniency program is restricted to the first reporting party and has $RF^{**} = \max\{RF^{*}, 0\}$, where RF^{*} is defined in Proposition 3;*

2. *The optimal law enforcement policy has $\gamma = 0$, $F = \overline{F}$, $RF = RF^{**}$ and $\alpha > 0$ and such that $c'_{\alpha}(\alpha)$ equals the marginal social benefit of deterrence.*

The first statement obtains because the reasoning behind Propositions 2 and Proposition 3 continues to apply when leniency programs are constrained to non-negative reduced fines (not to pay rewards). The constraint simply determines a corner solution ($RF = 0$) whenever the unconstrained optimal leniency program would require a reward. Since in the relevant parameter space ($\alpha < \frac{1}{2}$) it is $RF^{*} < 0$, in this region it will be $RF^{**} = 0$. The second part tells us that, as expected, with a moderate leniency program it will be generally optimal to spend resources to actively investigate cartels.

6.2 Deterrence effects of moderate leniency programs

The assumption of equal fines for first time and repeat offenders or of grim trigger strategies, together with $\gamma = 0$, may lead to conclude that a moderate leniency program cannot have deterrence effects. This is because the incentive to defect, the left hand side of condition (IC), is not reinforced by such a program: with $\gamma = 0$ a defecting agent does no better by reporting under a moderate leniency program than by defecting and not reporting, which is possible with or without the leniency program.[25]

However, the restriction to $\gamma = 0$, constant fines and grim trigger strategies is not empirically warranted: defecting from a cartel today does not usually guarantee not to be convicted

[24] An exception is the DoJ's "Amnesty Plus" program, where firms under investigation for one cartel are promised cancellation of otherwise due fines if they report other cartels they took part to. The cancellation of the fine represents then a positive monetary reward for the additional information provided.

[25] A previous version of this paper (Spagnolo 2000a) assumed $\gamma = 0$ and emphasized this "irrelevance result" for the case where firms use grim trigger strategies; analogous results are derived by Motta and Polo (2003) and Rey (2003), who also assume $\gamma = 0$ and grim trigger strategies.

for yesterday's wrongdoing (although we showed it would be optimal if it did); fines are typically higher for repeat wrongdoers; and grim trigger strategies are suboptimal for many oligopoly models, while real world punishment phases are often short and tough.[26]

Allowing γ to be positive, fines to be higher for repeat offenders, and firms to use other strategies than grim trigger ones breaks up the irrelevance result and unveils two reasons why even moderate leniency programs may have direct deterrence effects. Note first that the constraint $\underline{RF} = 0$ and Lemma 1 together imply that moderate leniency programs are never exploitable, so that the left hand side of condition (IC) does not change with their introduction ($V^c = V^{c\prime}$). Then, only effectivity considerations matter.

As long as there is a positive probability γ of being convicted for past collusive activities when one defects from collusive strategies the *protection from fines* effect is still at work: a moderate leniency program with $RF < \gamma F$ increases the value of defecting and reporting $V^{d\prime}$ by reducing the fine expected by a defecting agent from γF to RF, while leaving the value of colluding V^c unaffected. This effect is independent of which punishment strategies sustain collusion and of whether repeated offenders are punished more severely than first time offenders.

Even if the Legislator optimally sets $\gamma = 0$, if firms use two-phase "stick-and-carrot" punishment strategies à la Abreu (1986) and repeated wrongdoers are punished harder than first time one, a moderate leniency program may destabilize cartels by undermining the punishment phase that sustain them. We name this *protection from punishment* effect. With two-phase stick-and-carrot punishment strategies firms incur a cost when participating to the "stick" phase, and are willing to do it because it allows them to go back to the collusive "carrot" phase the following period. Suppose repeat wrongdoers are subject to higher expected fines than first time ones because fines for repeat wrongdoers F^r are higher than for first time offenders, or/and because the probability of detection α^r increase (buyers and the Antitrust Authority are now alerted of the collusive danger in the industry). When $\alpha^r F^r > \alpha F$, by transforming cartel members into repeat offenders a report under a leniency program reduces the expected value of further collusion, the "carrot", tightens the "no deviation constraint" for the punishment phase and reduces the strongest credible "stick" that can be used to deter defections in the first place.

This effect is best clarified with an example. Suppose the underlying game is à la Cournot, and that αF is sufficiently low that collusion is not deterred ($\pi^c - \alpha^r F^r > \pi^n$) and is enforced in equilibrium by optimal two-phase punishment strategies that guarantee $v^p < \pi^n$. Suppose further that repeat offenders face a much higher expected fine $\alpha^r F^r > \alpha F$ than first time one, so high that for them collusion is not individually rational ($\pi^c - \alpha^r F^r \leq \pi^n$). Without a leniency program, a defecting cartel member would not report, and firms would stick to

[26] An irrelevance result also appears inconsistent with the recent experience of the DoJ and the EC: since amnesty programs have been made clear and automatic (in 1993 in the US, in 2002 in the EU) many applications for leniency have been spontaneous reports, which suggests that moderate programs may indeed have direct destabilizing effects on cartels.

collusive strategies if

$$\frac{\pi^c - \alpha F}{1-\delta} \geq \pi^d - \gamma F - \frac{\delta v^p}{1-\delta}.$$

With a leniency program in place, instead, a defecting agent can at the same time report the cartel to the antitrust authority. To better isolate the protection from punishment effect, let us exclude the protection from fines effect by assuming $RF = \gamma F$.

By reporting under the leniency program, a defecting agent ensures that further collusion cannot be sustained because $(\pi^c - \alpha^r F^r \leq \pi^n)$. This excludes that other firms implement the original stick-and-carrot punishment, as there is no more "carrot" to repay for the cost incurred in the "stick" phase. The only Nash equilibrium left in the subgame following a report is the static Nash equilibrium, hence with a moderate leniency program in place, the condition for collusion being supportable becomes

$$\frac{\pi^c - \alpha F}{1-\delta} \geq \pi^d - \gamma F - \frac{\delta \pi^n}{1-\delta}$$

which, since $v^p < \pi^n$, is more stringent than in the absence of the leniency program.

Note that this protection from punishment effect may be strengthened when convicted wrongdoers are subject to imprisonment, as then their ability to punish the agent that defected and "turned them in" may be further constrained.

7 The *risk* of being cheated upon and "turned in"

There is at least one additional, important reason why moderate leniency programs may have direct deterrence effects: they may increase the perceived *riskiness* of entering or maintaining a collusive agreement.

In previous sections we assumed that as long as the IC condition was satisfied a collusive agreement could be sustained; i.e. that coordination on the collusive agreement and the risk of being cheated upon (and reported) were not serious problems. Under this assumption, to deter a cartel a leniency program had to ensure that the correspondent IC condition was violated. In this section we recognize that in reality to set up an effective collusive agreement agents must also establish “trust”, they realize that there is the *risk* of being cheated upon and reported hence they must be sufficiently confident that all agents will indeed stick to the agreement.

To give a formal account of the potential effects of leniency programs on the *riskiness* of collusive behavior and keep what we are doing intuitive for the reader, we restrict focus to a simplified version of our model where $N = 2$ and agreements are supported by grim trigger strategies, leave other features of the model unchanged.

Each period after having entered the collusive agreement, the two firms face the choice between sticking to the collusive equilibrium strategies, or abandoning them by defecting optimally and being then punished by their partners in the following periods. Restricting attention to the simultaneous, binary choice agents face in (any) one of the periods in which the cartel is in place, and calculating the discounted payoff flows generated by the two available actions ("stick to collusion" and "abandon collusion"), we obtain a two-by-two game to which one can apply the *risk dominance* considerations developed by Harsanyi and Selten (1988).[27]

7.1 Absent or ineffective leniency programs

When no leniency program is present ($RF = F$), or when the program is ineffective because it is not sufficiently generous ($RF > \gamma F$), for an agent that unilaterally defects from a collusive agreement it is optimal not to report information to the law enforcing agency. Then the optimal defection is "defect and don't report (in case there is something to report)". The bimatrix-form of the game representing (any) one period's decision along a collusive equilibrium path is then

no	c_2	d_2
c_1	V^c, V^c	B, D
d_1	D, B	$V^n - \gamma F$, $V^n - \gamma F$

,

where the values in the matrix are the discounted flows of payoffs agents expect, respectively:

when they both stick to the agreement, $V^c = \frac{\pi^c - \alpha F}{1-\delta}$;

when they unilaterally defect, $D = \pi^d - \gamma F + \delta V^n$, where $V^n = \frac{\pi^n}{1-\delta}$;

when their opponent unilaterally defects, $B = \pi^b - \beta F + \delta V^n$;

and when they both defect simultaneously, $V^n - \gamma F$.

We can apply Harsanyi and Selten's (1988) definition of risk dominance to this normal form game, by first transforming it into the best response-equivalent "unanimity game"

no'	c_2	d_2
c_1	$V^c - D$, $V^c - D$	0, 0
d_1	0, 0	$V^n - \gamma F - B$, $V^n - \gamma F - B$

,

and then calculating the "Nash products" of its two pure strategy equilibria

$$
\begin{aligned}
u_1(c_1,c_2)u_2(c_1,c_2) &= (V^c - \pi^d + \gamma F - \delta V^n)^2, \\
u_1(d_1,d_2)u_2(d_1,d_2) &= ((1-\delta)V^n - \gamma F - \pi^b + \beta F)^2 = \left(\pi^n - \pi^b + (\beta - \gamma)F\right)^2.
\end{aligned}
$$

[27] Harsanyi and Selten (1988) originally favored payoff-dominance over risk dominance as equilibrium selection criterion, but the theoretical and experimental support for risk dominance increased since then. Theoretical support has been offered by evolutionary game theory (Michihiro Kandori, George Mailath and Rafael Rob, 1993; Peyton Young 1993) and global games (Hans Carlsson and Eric van Damme, 1993), and experiments showed that agents priviledge risk and security considerations (John van Huyck, Raymond Battalio, and Richard Beil, 1990). Moreover, Harsanyi (1995) proposed later an alternative selection theory where he favoured risk dominance over payoff dominance.

The collusive equilibrium (c_1, c_2) is then riskier than abandoning collusion when

$$u_1(c_1, c_2)u_2(c_1, c_2) < u_1(d_1, d_2)u_2(d_1, d_2),$$

and the riskiness of (c_1, c_2) relative to (d_1, d_2) is measured by

$$\rho = u_1(d_1, d_2)u_2(d_1, d_2) - u_1(c_1, c_2)u_2(c_1, c_2).$$

With ineffective or absent leniency programs ($RF > \gamma F$) the riskiness of (c_1, c_2) is then

$$\rho^{no} = \left(\pi^n - \pi^b + (\beta - \gamma)F\right)^2 - \left(V^c - \pi^d + \gamma F - \delta V^n\right)^2.$$

Inspecting ρ^{no} one sees that also for strategic risk considerations, with poor or absent leniency programs it is optimal to set $\gamma = 0$. Increasing γ is costly and stabilizes collusive agreements, not only by making the IC condition less stringent (Proposition 1), but also by reducing the riskiness of criminal/collusive equilibria. Increasing α instead increases riskiness and deters collusive agreements. With $\gamma = 0$ and $\alpha > 0$ increases in fines increase the riskiness of collusion, and since higher fines imply no additional costs fines should be set maximal.

7.2 Effective leniency programs

Let us now consider how effective leniency programs ($RF \leq \gamma F$) affect the riskiness of the one-period decision to stick to a collusive agreement. If an agent defects from a collusive agreement it is now optimal for him to report information to the law enforcing agency, hence the optimal defection is: "defect and report (in case there is something to report), forever".

Consider leniency programs restricted to the first reporting party. The bimatrix-form of the game representing one period's decision problem on the collusive equilibrium path is now

rlp	c_2	d_2
c_1	$\max\{V^c, V^{c\prime}\}$ $\max\{V^c, V^{c\prime}\}$	B' D'
d_1	D' B'	$V^n - L$ $V^n - L$

,

where $D' = \pi^d - RF + \delta V^n$, $B' = \pi^b - F + \delta V^n$, and $L = \frac{RF+F}{2}$, and the riskiness of (c_1, c_2) is

$$\rho^{rlp} = \left(\pi^n - \pi^b + \frac{F - RF}{2}\right)^2 - \left(\max\{V^c, V^{c\prime}\} - \pi^d + RF - \delta V^n\right)^2.$$

When eligibility to the leniency program is not restricted, i.e. when the program offers the same reduced fine RF to first and second reporting agent, it is $D' = \pi^d - RF + \delta V^n$, $B' = \pi^b - RF + \delta V^n$, and $L = RF$, and the riskiness of (c_1, c_2) becomes

$$\rho^{ulp} = \left(\pi^n - \pi^b\right)^2 - \left(\max\{V^c, V^{c\prime}\} - \pi^d + RF - \delta V^n\right)^2.$$

Comparing the three measures of riskiness ρ^{no}, ρ^{rlp} and ρ^{ulp} we obtain the following.

Proposition 7 *Let $RF \leq \gamma F$. Then: (1) $\rho^{rlp} > \rho^{ulp}$; and (2) for non-exploitable leniency programs $\rho^{rlp} > \rho^{no}$.*

According to (1), collusive agreements are strictly more risky when eligibility to the leniency policy is restricted to the first reporting agent, than when it is open to all reporting agents. When the deterrence effects of leniency programs are due to the increase in the riskiness of collusion they generate, extending eligibility to leniency to other reporting agents than the first strictly reduces deterrence. The result is intuitively appealing, since when eligibility is not restricted a colluding agent is "safer" in the sense that he can always enjoy the fine discounts offered by the leniency policy by reporting, whatever other agents do. It reinforces Proposition 2 by offering further theoretical support to DoJ official's claim that the restriction of amnesty to the first applicant is crucial to the success of the leniency program, as it generates falls in trust and "rushes to report" among cartel members (e.g. Hammond, 2000).

According to (2), there are always restricted leniency programs that *strictly* increase the riskiness of collusive agreements (this is not true for unrestricted programs). Note that a restricted leniency program strictly increases the riskiness of collusion even when $RF = \gamma F$, i.e. when there is neither "protection from fines" nor "protection from punishment" (so that the "irrelevance result" would obtain with respect to the IC condition). The effect on the riskiness of collusion is therefore a third important reason why even the current moderate leniency programs may have the direct deterrence effects they appear to have.

In earlier versions we derived the optimal law enforcement policy under the assumption that agents do not collude when sticking to collusive strategies is risky. Policy prescriptions do not change: it is optimal to have maximal fines, a maximal reward restricted to the first reporting agent, and active investigations only if exogenous constraints on fines and rewards do not allow to reach the first best.

8 Concluding remarks

In this final section we briefly discuss some important aspects of the real world that could not be incorporated in the model.

Misreporting. Our stylized model with no mistakes in law enforcement highlighted the potential benefits of "high-powered incentives" in law enforcement policy. Of course, if one allows for more realism by introducing asymmetric information and mistakes, will find that there may be drawbacks in offering high rewards to law violators that spontaneously self-report. One potential drawback often put forward as a reason why (nowadays) rewards are seldom used is that these may induce agents to fabricate information. Indeed, the US prosecutors' practice of awarding reductions in sanctions and monetary rewards in exchange for testimony – "soft" information easy to fabricate – is a dangerous and highly debated one.[28] However, this potential drawback can be dealt with *directly* – restricting eligibility

[28] Some debated cases where US prosecutors exchanged rewards against testimony are discussed

to agents reporting "hard" information, not allowing only for testimony, and substantially increasing sanctions against information fabrication – rather that indirectly, by giving up the potentially large social gains from high-powered leniency programs.

Further research could clarify the issue (Aubert et al. 2004 make a first step in this direction, and appear to agree with our view), but we see at least two reasons why information fabrication may not be a major obstacle for the implementation of the optimal schemes proposed in this paper. First, the incentives to fabricate information created by rewards are fully analogous to those generated by the possibility to obtain damage settlements in private law suites and *Qui Tam* provisions when blowing the whistle against US government fraud (the 1986 amendments to the False Claim Act allow individual whistleblowers to cash up to 30% of all the funds recovered by the government). Nobody claims that damage payments should not be allowed for in private suits because they create incentives to fabricate information, and no problems of frequent information fabrication emerged with respect to rewarding whistleblowing against government fraud. Distinguishing reliable from unreliable information – and deciding on the base of the first – is the normal task of courts of justice, and fabricating information in a trial is subject to severe criminal sanctions that can be further increased.

Second, innocent parties accused by an agent who fabricated information will have all the incentives – and in the case of cartels the financial resources – to fight back and demonstrate their innocence and the first agent's wrongdoing. Fabricating information to cash rewards appears therefore an extremely risky activity.

Damages. When a cartel is successfully prosecuted, *all* former cartel members, including firms that self-reported and cooperated with the Antitrust Authority, are exposed to suits for damages from their customers. How does this feature of reality affects our analysis? Taking damages into account in a simple way does not alter our conclusions. Let $E[D] > 0$ denote the damages a firm expects to pay if convicted for collusive behavior, and $E[RD] \geq 0$, the damages a firm that spontaneously self-reports expects to pay, with $E[RD] \leq E[D]$ (at present both in the EU and US it is $RD = D$, but in light of our previous results it is not hard to see why one may wish to protect reporting firms by setting $E[RD] < E[D]$). Now let us redefine variables in the previous sections so that $F = MF + E[D]$ and $RF = RMF + E[RD]$, where MF and RMF stand for fines and reduced fines respectively. It is immediate to verify that all our results continue to apply, with the only (important) difference that fine reductions/rewards must be increased to compensate for expected damage payments. Moreover, if we allow $E[RD]$ and $E[D]$ to differ, it becomes clear that as long as increasing rewards for self-reporting firms is more costly than modifying the law to protect them from damage suits, the Legislator's optimal policy is to set $E[RD] = 0$. In practice, this implies that *present leniency programs are not even constrained-optimal*: they would be optimal moderate

at *http://www.pbs.org/wgbh/pages/frontline/shows/snitch/readings/paying.html*paying.html Reporting agents were asked to testify even though the provisions of 18 USC Section 201(c)(2) explicitely makes it an offense to pay a witness for testifying. As mentioned, we regard as a mistake to ask reporting agents to testify when they receive leniency. In this paper we excluded testimony assuming that to obtain leniency an agent must provide "hard" information (videotapes, documents, etc.).

programs only if they would protect a reporting firm from being sued for damages. Taking into account that damages grow with the life of a cartel is a more interesting and difficult task, as the pricing behavior of the cartel becomes then a function of history (see Harrington 2003). Though, at this stage we do not see reasons why the qualitative conclusions reached in this paper should be affected by damage payments (or fines) increasing with cartel duration.

Restitution. According to the US Corporate Leniency Program, to obtain leniency self-reporting firms are required to pay back collusive profits to customers (if this does not drive them bankrupt; see Spratling, 1998). It is easy to verify that when self-reporting firms must pay back realized collusive profits to customers, the attractiveness of defecting and reporting is reduced. As for damages, then higher fine discounts/rewards are needed to compensate for these additional losses if one wishes to deter cartels by inducing firms to spontaneously self-report. The restitution requirement is unambiguously counterproductive and should be simply removed.

Individuals vs. Organizations. In the paper we focused on generic agents or firms. In reality, agents of criminal organizations are sometimes themselves organizations composed of many individuals. This is the case for cartels, whose members are firms (sometimes conglomerates). Allowing individual managers or other employees to cash the rewards discussed in this paper (the sum of all fines paid by convicted firms) by reporting information on a cartel in which their own firm is involved, exponentially increases the power of incentives to report, hence the deterrence effects of the program. However, individual leniency programs may undermine trust not only between, but also within each colluding firms, which may be socially costly. Aubert et al. (2004) focus on the costs and benefits of individual leniency programs, and argue that the benefits appear larger than the potential costs.

Violence. Criminal organizations often arrange for credible, violent sanctions against members that turn them down. This may even be true for cartels. For example, according to Diego Gambetta and Peter Reuter (1995) in Sicily the Mafia has met the enforcement demand of oligopolistic firms with a supply of coordination and (rather effective) enforcement services, particularly in procurement auction markets. In these situations, firms (or executives) that self-report risk their life, and leniency programs must try to compensate for this risk by providing effective protection besides sufficiently high rewards.

Other issues. Our model can be extended in various directions to shed light on important related issues. It would be interesting to allow for a smaller probability of conviction after a report, and to make it an increasing function of further parties' reports. This may allow to study the optimal reduction in fine discounts to award to reporting parties other than the first, creating a link between this model and Motta and Polo (2003). It would also be interesting to introduce judicial mistakes, and check whether and how these may affect the optimal design of leniency programs. Another interesting research avenue is considering the possibility that - independent of violence - cartels use a "fit-the-crime" punishment scheme to discipline their members, in which case undercutting and self-reporting would be met with tougher sanctions than just undercutting. The US experience with *Qui Tam* provisions for whistleblowers on government fraud showed that this may be a serious problem: whistelblowers are typically subject to severe retaliation from their organizations. The possibility that law enforcers (judges, juries) are averse to rewarding guilty agents could also be modelled, as well as the possibility that law enforcers are not fully benevolent. In both cases the leniency program would affect criminal prosecution and procedure, and maximal rewards may no more be optimal. Finally, since empirical analysis of deterrence effects is precluded by the non-observability of criminal activities, the deterrence effect of leniency programs on cartels appears a perfect topic for more experimental analysis.

9 Appendix

9.1 Proofs

Proof of Proposition 1. Fines are costless to administer and, being transfers, do not directly affect social welfare, hence an optimal law enforcement policy sets them to maximize crime/cartel deterrence by making inequality (2) as stringent as possible. The conditions in the statements obtain by differentiating (2). $V^c = \frac{\pi^c - \alpha F}{1-\delta}$, $V^d = \pi^d - \gamma F + \frac{\delta v^p}{1-\delta}$, $V^c - V^d = \frac{\pi^c - \alpha F}{1-\delta} - \pi^d + \gamma F - \frac{\delta v^p}{1-\delta}$

$$\frac{\partial (V^c - V^d)}{\partial F} = \frac{-\alpha}{1-\delta} + \gamma - \frac{\delta}{1-\delta}\frac{\partial v^p}{\partial F}$$

which is negative as long as

$$\gamma < \frac{\alpha}{1-\delta} + \frac{\delta}{1-\delta}\frac{\partial v^p}{\partial F}$$

and positive otherwise.

An optimal law enforcement policy maximizes deterrence by making condition (2) as stringent as possible while minimizing enforcement costs (c_k). Since $\frac{\partial(V^c - V^d)}{\partial \gamma} = F \geq 0$, when $F > 0$ condition (2) is more stringent the smaller is γ. This and $c'_\gamma > 0$ imply that setting $\gamma = 0$ and $F = \overline{F}$, is optimal. ■

Proof of Lemma 1. If all firms are eligible $V^{c\prime} = \frac{\pi^c - RF}{1-\delta}$, and since $V^c = \frac{\pi^c - \alpha F}{1-\delta}$, $V^{c\prime} > V^c$ when $RF < \alpha F$. If only one firm is eligible, again $V^c = \frac{\pi^c - \alpha F}{1-\delta}$, but now $V^{c\prime} = \frac{\pi^c - \frac{(N-1)F + RF}{N}}{1-\delta}$, and

$$\begin{aligned} V^{c\prime} - V^c &= \frac{\alpha F - \frac{(N-1)F+RF}{N}}{1-\delta} = \frac{\alpha F - (N-1)(1-\alpha)F - RF}{N(1-\delta)} > 0 \text{ when} \\ RF &< N\alpha F - (N-1)F \text{ or } RF < \alpha F - (N-1)(1-\alpha)F. \end{aligned}$$

■

Proof of Lemma 2. Without leniency programs $V^d = \pi^d - \gamma F + \frac{\delta v^p}{1-\delta}$. With the leniency program, the value of defecting is $V^{d\prime} = \pi^d - RF + \frac{\delta v^p}{1-\delta}$. Independent of how many firms are eligible $V^{d\prime} > V^d$ when

$$\begin{aligned} V^{d\prime} &= \pi^d - RF + \frac{\delta v^p}{1-\delta} > \pi^d - \gamma F + \frac{\delta v^p}{1-\delta} = V^d \\ &\Rightarrow RF < \gamma F. \end{aligned}$$

■

Proof of Proposition 2. Follows directly from Lemma 1 (restricting eligibility reduces $V^{c\prime}$) and Lemma 2 (restricting eligibility does not affect $V^{d\prime}$). ■

Proof of Proposition 3. An optimal leniency program makes the inequality $\max\{V^c, V^{c\prime}\} > \max\{V^d, V^{d\prime}\}$ as stringent as possible. The leniency program is exploitable if $RF < \alpha F -$

$(1-\alpha)(N-1)F$, and is effective if $RF < \gamma F$. For the relevant parameter range ($\alpha < \frac{1}{2}$ and $N \geq 2$) it is $\alpha F - (N-1)(1-\alpha)F < 0 < \gamma F$. Then:

In the region $RF > \gamma F$ the leniency program is irrelevant, it is neither exploitable nor effective.

In the region $\alpha F - (N-1)(1-\alpha)F < RF < \gamma F$ the program is effective ($V^{d\prime} \geq V^d$) and is not exploitable ($V^{c\prime} < V^c$). From Lemma 2 we know that $V^{d\prime}$ is decreasing in RF, so that in this region it is optimal to decrease RF to make the IC condition more stringent by increasing its right hand side.

In the region $RF \leq \alpha F - (N-1)(1-\alpha)F$ the program is both effective and exploitable, and a reduction of RF increases both the left and the right hand side of condition IC. When $RF \leq \alpha F - (N-1)(1-\alpha)F$ condition IC can be written as

$$\begin{aligned} V^{c\prime} &\geq V^{d\prime} \Leftrightarrow \frac{\pi^c - \frac{(N-1)F+RF}{N}}{1-\delta} \geq \pi^d - RF + \frac{\delta v^p}{1-\delta} \\ &\Leftrightarrow \quad \delta \geq \underline{\delta} = \frac{\pi^d - \pi^c + \frac{N-1}{N}(F-RF)}{\pi^d - v^p - RF} = \frac{\pi^d - \pi^c + \frac{N-1}{N}F - \frac{N-1}{N}RF}{\pi^d - v^p - RF}, \end{aligned}$$

and

$$\begin{aligned} \frac{\partial \underline{\delta}}{\partial RF} &= \frac{-\frac{N-1}{N}(\pi^d - RF - v^p) + (\pi^d - \pi^c + \frac{N-1}{N}(F-RF))}{(\pi^d - RF - v^p)^2} \\ sign\left(\frac{\partial \underline{\delta}}{\partial RF}\right) &= sign\left\{-\frac{N-1}{N}(\pi^d - v^p) + \pi^d - \pi^c + \frac{N-1}{N}F\right\} \\ &= sign\left\{\pi^d + (N-1)(v^p + F) - N\pi^c\right\} > (<)0 \\ \text{if } F &> (<)\pi^c - v^p - \frac{\pi^d - \pi^c}{N-1}. \end{aligned}$$

■

Proof of Proposition 4. Parameters γ and β do not affect the IC condition and are costly to increase, hence their optimal level is $\gamma = \beta = 0$. Since we assumed $\delta < 1$, setting $\alpha = 0$ to keep at zero investigation costs and letting F and $-RF$ grow simultaneously respecting the no-exploitation constraints, the IC condition for our representative agreement becomes more stringent (the left hand side V^c is independent of RF and F, while the right hand side $V^{d\prime}$ increases with F). Hence there exist a finite level of the fine F' such that for fines higher than this level the IC condition is not satisfied. Since this is true for any conceivable collusive agreement, the statement follows.■

Proof of Proposition 5. Again, setting $\gamma = \beta = 0$ is optimal because increasing them is costly and does not make the IC condition more stringent, and setting $F = \overline{F}$, is optimal because it makes the IC more stringent than at any other level of fines, while raising fines is not costly. In addition:

1) When $F > \pi^c - v^p - \frac{\pi^d - \pi^c}{N-1}$, $RF^* = \alpha F - (N-1)(1-\alpha)F$ and the IC condition is

$$\frac{\pi^c - \alpha F}{1-\delta} \geq \pi^d - \alpha F + (N-1)(1-\alpha)F + \frac{\delta v^p}{1-\delta}$$
$$\Leftrightarrow \delta \geq \underline{\delta} = \frac{\pi^d - \pi^c + (N-1)(1-\alpha)F}{\pi^d - v^p - \alpha F + (N-1)(1-\alpha)F}.$$

Since

$$\begin{aligned}
\frac{d\left(\underline{\delta}\right)}{d\alpha} &= \frac{-(N-1)F(\pi^d - v^p - \alpha F + (N-1)(1-\alpha)F) + (NF + \frac{\partial v^p}{\partial \alpha})(\pi^d - \pi^c + (N-1)(1-\alpha)F)}{(\pi^d - v^p - \alpha F + (N-1)(1-\alpha)F)^2} \\
&= \underbrace{\frac{\partial v^p}{\partial \alpha}(\pi^d + (N-1)(1-\alpha)F - \pi^c)}_{>0} + \underbrace{F(\pi^d + (N-1)(1-\alpha)F + (N-1)(v^p + \alpha F) - \pi^c N)}_{A} \\
A &= \pi^d - \pi^c - (N-1)[\pi^c - F - v^p] > 0 \text{ when} \\
(N-1)F &> \pi^c - \pi^d + (N+1)[\pi^c - v^p] > 0 \\
&\Leftrightarrow F > \pi^c - v^p - \frac{\pi^d - \pi^c}{N+1} > 0, \text{ as assumed.}
\end{aligned}$$

Since increasing α increases deterrence by making the IC condition more stringent, if complete deterrence is not achieved at $\alpha = 0$ and $RF^* = -(N-1)F$, and if $c'_\alpha(0)$ is smaller than the marginal social benefit of further deterrence, it is optimal to set $\alpha > 0$ and $RF^* = \alpha F - (N-1)(1-\alpha)F < -(N-1)F$.

2) When $F < \pi^c - \pi^n - \frac{\pi^d - \pi^c}{N-1}$, $RF^* = -(N-1)F$ and the IC condition is

$$\frac{\pi^c - \frac{(N-1)F + RF}{N}}{1-\delta} \geq \pi^d - RF + \frac{\delta \pi^n}{1-\delta},$$
$$\Leftrightarrow \delta \geq \underline{\delta} = \frac{\pi^d + (N-1)F - \pi^c}{\pi^d + (N-1)F - \pi^n}.$$

This is the best exploitable program. The best non-exploitable one (with $RF > \alpha F - (N-1)(1-\alpha)F$) delivers

$$\delta \geq \underline{\delta}' = \frac{\pi^d + (N-1)(1-\alpha)F - \pi^c}{\pi^d - \alpha F + (N-1)(1-\alpha)F - v^p},$$
$$\text{where } \frac{\partial \underline{\delta}'}{\partial \alpha} < 0 \text{ since } F < \pi^c - v^p - \frac{\pi^d - \pi^c}{N-1}.$$

Hence $\alpha = 0$ and $RF^* = \underline{RF} = -(N-1)F$ is the global optimum.■

Proof of Proposition 6. The first part follows immediately from Propositions 3 and 4. For the second part, setting $\gamma = \beta = 0$ is optimal because increasing them is costly and does not affect the IC condition, and setting $F = \overline{F}$ is optimal because it makes the IC more stringent at no cost. For the relevant parameters range ($\alpha < \frac{1}{2}$) it is

$$RF^{**} = 0 > \alpha F - (N-1)(1-\alpha)F > -(N-1)F,$$

so that the program is never exploitable and the IC condition is $V^c > V^{d\prime}$. Since $\frac{\partial V^c}{\partial \alpha} < 0$ and $\frac{\partial V^{d\prime}}{\partial \alpha} = 0$, increasing α increases deterrence by making the IC condition more stringent. Hence if complete deterrence is not achieved at $\alpha = 0$ and if $c'_\alpha(0)$ is smaller than the marginal social benefit of further deterrence, it is optimal to set $\alpha > 0$. ■

Proof of Proposition 7. Restricting eligibility to the leniency program is optimal if $\rho^{rlp} > \rho^{ulp}$, or

$$\begin{aligned} \left(\pi^n - \pi^b + \frac{F - RF}{2}\right)^2 &> \left(\pi^n - \pi^b\right)^2 \Leftrightarrow \\ \frac{F - RF}{2} &> 0, \end{aligned}$$

which is always satisfied when $RF \leq \gamma F$. Introducing a restricted leniency program is optimal if it increase riskiness without raising costs $\rho^{rlp} > \rho^{no}$. Considering a non-exploitable leniency program

$$\begin{aligned} \rho^{rlp} &> \rho^{no} \Leftrightarrow \\ &\left(\pi^n - \pi^b + \frac{F - RF}{2}\right)^2 - \left(V^c - \pi^d + RF - \delta V^n\right)^2 \\ &> \left(\pi^n - \pi^b + (\beta - \gamma)F\right)^2 - \left(V^c - \pi^d + \gamma F - \delta V^n\right)^2 \end{aligned}$$

which is always satisfied because $\beta < \frac{1}{2}$ and $RF \leq \gamma F$. ■

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