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"Io so. Ma non ho le prove. Non ho nemmeno indizi." Pier Paolo Pasolini. Il corriere della sera. 1974.

Abstract

We present a model where the Antitrust Authority is privately informed about the strength of the case against a given cartel. In this context, the Antitrust Authority may obtain cartel members' confessions even when it opens an investigation knowing that it has no chance to find hard evidence. More generally, we show that offering leniency allows to raise the conviction rate, which in turn enhances cartel desistance and cartel deterrence. A second contribution of the paper is to show that the optimal leniency scheme involves a *single informant* rule. That is, amnesty should be given only if a unique cartel member reports information.

Keywords: Antitrust law and policy; Cartels; Collusion; Self-reporting.
JEL classification codes: K42, K21, L41.

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1 Introduction

Both the Department of Justice (DoJ) in the United States (US) and the Commission in the European Union (EU) have made a top priority of breaking up cartels. This is reflected in the recent sharp increase in the amount of penalties inflicted on cartel members.[1] In the EU, the record fines of €1,383 million against car glass makers in 2008 is another illustration: these are the highest penalties the European Commission has ever imposed, both for an individual company (€896 million on Saint Gobain) and for a cartel as a whole, beating the €992 million fine against elevator and escalator makers in 2007.

A path-breaking development in the US antitrust policy was the revision of its corporate leniency program in 1993. Under the old version,[2] discretionary leniency was granted to confessors provided that the cartel was not already under investigation. The new program instead automatically guarantees full amnesty to the first firm who blows the whistle in this case; in addition, some leniency may be granted when an investigation has begun. Finally, the DoJ added a complementary individual leniency program in 1994 that protects individual informants from pecuniary fines or criminal sanctions.[3] Since its revision in 1993, the corporate leniency program has been the DoJ's most effective investigative tool; it helped to dismantle large global cartels such as the Vitamins or Graphite Electrodes cartels.[4] The commonly used argument to explain the success of the US leniency program is the implementation of first informant rules combined with large expected fines. This "stick and carrot" logic motivated the recent revisions (2002 and 2006) of the European leniency program which turns out to be also highly effective in fighting against cartels.[5] In recent years, around two thirds of the successful investigations carried out by the European Commission have been initiated after one cartel member asked for leniency.

The claimed efficiency of leniency programs has to be taken with caution, however. First, measuring the direct effect on deterrence is a real challenge since one can only observe detected cartels. In addition, antitrust authorities tend to overstate their investigative capabilities and the efficiency of their amnesty schemes. The two previous points call for both theoretical and empirical research.

[1]In the US, corporate fines averaged \$315 million per year between 1995 and 1999 and \$560 million between 2005 and 2007. In the EU, the rise is impressive, going from €68 million per year between 1995 and 1999 to €1,955 million between 2005 and 2007 (data from the US Antitrust division and the European Commission). One condition of this surge was the increase in the legal cap. In the US, the Congress raised in 1990 the maximum fine for Sherman Act violations from \$1 million to \$10 million. This statutory limit has been \$100 million since 2004. Alternatively, since 1987, fines can be set equal to twice the convicted firms' pecuniary gains or twice the victims' losses. In the EU, firms may be fined up to 10 % of their turnover.

[2]The DoJ installed the first corporate leniency program in its antitrust regulation in 1978.

[3]In the EU, violations of Article 81 and 82 are not punished with criminal fines. In particular, individuals are not subject to imprisonment.

[4]The vitamin cartel was cracked in 1999 by the cooperation of the company Rhône-Poulenc SA. The main co-inspirators Hoffmann-La Roche and BASF paid in the US fines of respectively \$500 million and \$225 million while the penalty was waived for Rhône-Poulenc. In the graphite electrodes case (1999), the cooperative firm played only a secondary role in the cartel but its initial information allows the DoJ to gather additional evidence that led to the guilty pleas of the other conspirators. In total, firms paid \$400 million and three individuals received jail sentences (from 9 to 17 months).

[5]For a discussion of the differences and similarities between the US and the EU leniency programs, see Spagnolo's review (2007).

While the theoretical literature, starting with Motta and Polo (2003) and Spagnolo (2004), has confirmed that a well-designed leniency scheme can significantly contribute to destabilize cartels, it has also pointed out some pro-collusive effects. Concerning deterrence effects, Spagnolo (2004) and Rey (2003) note that leniency increases gains from deviations by allowing defecting cartel members to report and avoid facing the fine. Spagnolo (2004) moreover shows that granting the first informant a reward equal to the sum of the fines imposed on the other conspirators can achieve full deterrence. In parallel, Aubert, Rey and Kovacic (2006) argue that rewarding individuals also helps to destabilize collusion since firm employees must then be "bribed" to be kept silent. Several papers however identify perverse effects that may dilute deterrence. Leniency reduces expected sanctions and thus increases the value of "collude and report" strategies (Motta and Polo (2003), Spagnolo (2004)). Moreover, badly designed leniency programs may contribute to stabilize collusion by giving cartel members a tool to punish deviators (Buccirossi and Spagnolo (2006) in the context of bilateral illegal transactions). Note that restricting eligibility to the first informant reduces the risk of these two perverse scenarii.

The main obstacle to empirical analysis is that collusive agreements are secret. That is why the existing recent empirical literature has been obliged to use indirect methods to assess the impact of leniency programs on cartels behavior (Brenner (2009), Harrington and Chang (2009), Miller (2009)).[6] Harrington and Chang (2009) develop a model of cartel formation and dissolution which enables to test the efficiency of a new cartel enforcement tool. In particular, the deterrence effects of leniency may be assessed through the short-run changes in the duration of discovered cartels. The alternative framework of Miller (2009) allows to infer changes in the formation rates directly from changes in the number of detected cartels. He applies his findings to information reports issued by the DoJ between 1985 and 2005 and shows that the pattern of cartel discoveries around the revision in 1993 of the US corporate leniency program is consistent with enhanced cartel detection and deterrence capabilities. By contrast, Brenner (2009)'s work on European data shows that the introduction of a leniency policy in Europe in 1996 (without a first informant rule and full leniency) had no clear effect on deterrence. This suggests that the design of leniency schemes is a key element of success.

For cartels that are too stable to be deterred, antitrust authorities must try to detect and crack them down. The recent conviction of the car-glass makers highlights the role of post-investigation leniency in the prosecution of cartels. According to the European Commission:

"The Commission started this investigation on its own initiative on the basis of reliable information provided by an anonymous informant. The information prompted the Commission to carry out surprise inspections in 2005 at several sites of car glass producers in Europe. After the inspections, the Japanese Asahi Glass Co. and its European subsidiary AGC Flat Glass Europe (formerly 'Glaverbel) filed an application under the 2002 Leniency Notice.... Asahi/Glaverbel cooperated fully with the Commission and provided additional information to help to expose the infringement and its fine was reduced by

[6] Note that experiments are another means to obtain empirical predictions. See for example Apesteguia et al. (2007), Bigoni et al. (2008) and Hinloopen and Soetevent (2008).

50%."[7]

We can infer from the *Commission Notice on Immunity from Fines* (2006) that the inspections have not been entirely successful since the notice specifies that:

> *"in order to qualify [for reduction of a fine], an undertaking must provide the Commission with evidence of the alleged infringement which represents significant added value with respect to the evidence already in the Commission's possession".*

The period following an investigation is generally a fool's game. The antitrust authority must convince cartel members that the risk of conviction is real if it wants them to report their own pieces of information. This pushes the antitrust authority to over-represent its own evidence and investigative power. In particular, it may run an investigation against a cartel pretending that conviction is very likely in the hope that firms will denounce themselves the cartel. We build our model on this idea.

Formally, we consider a standard supergame where firms decide whether to compete or collude on the market. The Antitrust Authority cannot condemn the cartel without gathering hard evidence. When firms collude, the Antitrust Authority receives a binary signal (either good or bad) which determines the probability of convicting cartel members if an investigation is launched. This probability is low when the signal is bad. As cartel members do not observe the Antitrust Authority's signal, they may confess their illegal activities even when the Antitrust Authority opens an investigation after receiving a bad signal. In such a case, the cartel is condemned even though the Antitrust Authority was unlikely to convict firms by its own means.

Our paper is related to Motta and Polo (2003). In their paper, offering leniency enables the Antitrust Authority to save on prosecution costs, and the freed resources reinforce detection capabilities. However, the leniency policy gives amnesty to all firms that apply for leniency, which has a negative impact on cartel deterrence. As a result, the leniency program is a second-best instrument: if the budget of the Antitrust Authority is large enough to deter cartel formation, leniency should not be offered. One important innovation in our paper is the incorporation of private information on the Antitrust Authority side. We shall show that this informational advantage, combined with leniency, allows the Antitrust Authority to raise the overall conviction rate and thereby to enhance cartel desistance. The design of the leniency scheme – for instance, implementing or not a first informant rule – ensures that the increase in the conviction rate also materializes into higher deterrence.

The paper is organized as follows. Section 2 describes the model. Section 3 provides a benchmark where there is no information asymmetry between the Antitrust Authority and cartel members. Section 4 studies the case where the Antitrust Authority has private information about the strength of its case against a given cartel. Section 5 derives the optimal informant rule. In section 6, we discuss some policy implications. Finally, section 7 concludes.

[7] available at http://ec.europa.eu/competition/cartels/what_is_new/news.html, reference: IP/08/1685.

2 The Model

2.1 Players

2.1.1 Firms

We consider a continuum of industries with unit mass. In each industry, $N \geq 2$ symmetric and risk-neutral firms play an infinitely repeated game. In each period, each firm decides whether to compete or collude. The gross profit of a firm is:

- $\Pi^C \geq 0$ if firms compete,
- $\Pi^{Col} > \Pi^C$ if firms collude,
- $\Pi^D > \Pi^{Col}$ if the firm deviates from collusion – that is, if it competes when the other firms collude.

In order to analyze the impact of the antitrust policy on cartel formation, we allow industries to vary in the scope for collusion by assuming that industries are heterogenous with respect to Π^D.

We focus on explicit collusion, which is based on communication, meetings and so forth. We therefore assume that successful collusion automatically generates hard evidence that the Antitrust Authority needs to find out in order to condemn the cartel. All firms have the same discount factor $\delta \in (0, 1)$ and maximize the expected discounted sum of their profits.

We focus on grim trigger strategies in which any deviation from a collusive agreement is punished by reverting forever to competition, which is here the minmax and thus constitutes the most severe punishment.

2.1.2 Antitrust Authority (AA)

The AA is aware whether an industry colludes, but cannot condemn a cartel without gathering hard evidence of collusion. That is, we focus on prosecution rather than on detection.[8] In each period of collusion, the AA receives a binary signal $S \in \{g, b\}$ which determines the probability of finding hard evidence if it launches an investigation. Conditional on there being a cartel, the probability to receive a good signal is ψ. If the realization of the signal is good ($S = g$), the AA knows that it will find hard evidence of collusion with probability $\mu < 1$ if it runs an investigation. If the realization of the signal is instead bad ($S = b$), the AA has no chance to find hard evidence with its own investigation.[9]

[8]The assumption that the AA perfectly observes whether collusion occurs is made for simplicity. Our results are qualitatively unchanged if we assume instead that the AA receives signals strongly correlated with the presence of collusion. Our model similarly applies to organized crime (corruption, mafias, drug trafficking and so on) where prosecution – i.e., finding enough evidence to obtain a condemnation in court – is a relatively more important issue than detection.

[9]Section 6 discusses the case where the probability of finding evidence during an investigation is also positive in case of a bad signal.

When firms collude, the AA decides whether or not to run an investigation depending on the realization of the signal. If the AA has gathered hard evidence at the end of the period, the cartel is condemned and each member must pay a fine F, which is exogenously set by law.[10]

Leniency Program. If a leniency program is implemented, eligible firms pay only a reduced fine if they report information, in which case all cartel members are condemned with probability one. The AA fixes a *pre-investigation* leniency rate q_0, available before the beginning of any investigation, and a *post-investigation* leniency rate q, available during investigations. We restrict our attention to leniency rates lower than one.[11] To facilitate the exposition of the results, we first constrain the AA to choose between granting leniency to all informants or instead adopting a *first informant* rule (denoted hereafter FI rule) – i.e., to restrict eligibility to the first confessor. Then, in section 5, we expand the set of feasible schemes by allowing the AA to offer leniency rates contingent on the number of informants, and we derive in this context the optimal leniency scheme. Finally, following a condemnation, firms are forced to compete forever.[12] Enforcing competition can for example be achieved through either close monitoring of the industry[13] or higher fines for repeat offenders.[14]

Information. Except in the benchmark case, the realization of the signal is unknown to cartel members. The measures of prosecution efficiency ψ and μ, as well as the parameters of the antitrust scheme q_0, q and F are common knowledge.

In practice, the signal S may be obtained during a sector inquiry. According to the European Commission:

"The Commission may decide to start a sector inquiry when a market does not seem to be working as well as it should. This might be suggested by evidence such as limited trade between Member States, lack of new entrants on the market, the rigidity of prices, or other circumstances suggest that competition may be restricted or distorted within the common market".

Alternatively, the realization of the signal may be interpreted as whether the AA re-

[10]Alternatively, F may be viewed as the maximal punishment allowed by the law. In this case, Becker's (1968) argument applies: it is optimal to set fines as high as possible. An infinite fine combined with a positive, even arbitrarily low enforcement probability necessarily deters cartel formation.

[11]Well-designed reward schemes are very effective in fighting collusion (see Spagnolo (2004) and Aubert, Rey and Kovacic (2006)). Authorizing rewards in our setting would also deter collusion in all industries. However, in practice, it is generally politically unfeasible.

[12]This assumption is made for simplicity. Our results are qualitatively unchanged if we assume instead that firms are forced to compete only for a finite positive number of periods following a condemnation.

[13]In the context of organized crime, imprisonment can also stop an illegal practice.

[14]Higher fines for repeat offenders are present in US and European antitrust laws.

ceived some initial incriminating evidence from third parties.[15,16] Accordingly, ψ is likely to vary in practice with the efficiency of existing schemes designed to encourage whistleblowing. In particular, sentencing individuals to imprisonment[17] or offering bounties[18] to informants strongly incentivize third parties' cooperation.[19] The US Amnesty Plus Program, which gives strong financial incentives to firms already under prosecution for denouncing cartels in other markets,[20] is also an efficient instrument to raise the probability of obtaining initial evidence on separate cartels.[21] As for μ, it is likely to vary with the AA's budget, and also with technological progress, for instance the use of digital forensics.

[15] Third parties can be internal employees, buyers' complaints or local agencies. Internal whistleblowing is encouraged in the US by the Individual Leniency Program. Several recent cases in the US were initiated by buyers' complaints such as the graphite electrodes and the stainless steel cartels. Infiltration may complement individual whistleblowing: a well-known example is the use of covert cameras by the FBI to tape cartel meetings leading to the conviction of the international Lysine cartel. Note that the recordings have been facilitated by a cooperating witness. For more detailed information on the prosecution of the Lysine cartel, see Hammond (2005).

[16] We could furthermore assume that the initial evidence is more or less reliable, which would justify the stationarity of the model. Suppose for example that a good signal means that the initial evidence is reliable with probability ψ, in which case an investigation will be successful for sure, and is otherwise unreliable, in which case an investigation cannot succeed. If the AA launches an investigation, either the cartel is condemned and the game thus ends for that industry, or the investigation fails and the AA will then infer that its initial evidence was not reliable.

[17] Hammond (2007) declared:

"The Division has long emphasized that the most effective way to deter and punish cartel activity is to hold culpable individuals accountable by seeking jail sentences".

The Antitrust Criminal Penalty Enhancement and Reform Act of 2004 raised the maximum jail term available under the Sherman Act from three years to ten years. Nonetheless, the US (and Canada) are nearly alone in the world in sending cartel managers in jail. The possibility to fine individuals is also written in the law of other countries (for example Germany, France, Japan) without being applied.

[18] In practice, very few jurisdictions offer financial rewards for whistleblowers. Notable exceptions are the UK and South Korea. The UK's Office of Fair Trading has been offering since March 2008 rewards of up to £100,000 for information about cartel activity. The Informant Reward System has been introduced in April 2005 by the Korean Fair Trade Commission and recompenses those who report competition law violations. In June 2005 a first reward of 66,87 million won (about $ 63,700) was paid to an anonymous person who provided decisive evidence (names of executive of the 6 cartel members, meeting place and details of agreements) in a welding rod cartel case. In the US, Kovacic (2001) proposes to expand the existing Civil False Claims Act (adopted by the Congress in 1863 and reinforced in 1986 which offers rewards in exchange of information given to the government in procurement fraud cases) to price-fixing violations.

[19] Spagnolo (2007) mentions the sociological literature documenting that whistleblowers experience a terrible working, social and private life after reporting. This suggests that whistleblowing are very unlikely without high rewards.

[20] Disclosing a second cartel lead to amnesty for the second offense, together with a substantial reduction in the fine for the participation in the first cartel.

[21] Griffin (2003) declared:

"Roughly half of the Division's current international cartel investigations were initiated by evidence obtained as a result of an investigation of a completely separate market."

2.2 Timing

First, in stage 0, the AA fixes q_0 and q at the beginning of the game together with possible restrictions such as a FI rule. Moreover, it announces and sticks to an investigation policy (more on this below). Then, in each period, the timing of the game, summarized in Figure 1, is as follows:

- Stage 1. Each firm chooses whether to enter into a collusive agreement. If at least one firm chooses not to collude, competition takes place and the game moves to the next period. If all firms choose to enter into a collusive agreement, this decision leaves hard evidence of collusion and the game proceeds to stage 2.

- Stage 2. Each firm chooses whether to respect the agreement and collude, or to deviate and compete on the market. These decisions are not observed by the other firms until the end of the period.

- Stage 3. Each firm decides whether to apply to the *pre-investigation* leniency program and report evidence of collusion to the AA. If at least one firm reports information, the cartel is condemned; in that case, eligible firms benefit from a reduced fine $(1 - q_0)F$. Otherwise, the game proceeds to stage 4.

- Stage 4. The AA receives the signal S and decides whether or not to run an investigation. This decision is publicly observed by firms. If the AA runs an investigation, the game proceeds to stage 5.

- Stage 5. Each firm decides whether to apply to the *post-investigation* leniency program. If at least one firm reports, the cartel is condemned; in that case the fine is reduced to $(1 - q)F$ for the eligible firms. Otherwise, the game proceeds to stage 6.

- Stage 6. If the AA received a good signal, it finds hard evidence and can thus condemn the cartel with probability μ. If the signal is bad, the AA has no chance to gather evidence of collusion.

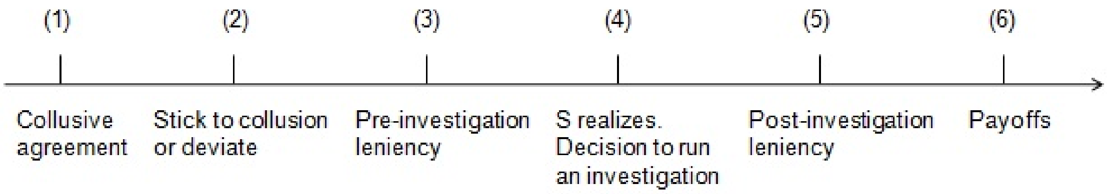


Figure 1: The stage game

2.3 Strategies

We focus on stationary strategies.[22]

Antitrust Authority. As mentioned above, the investigation policy is contingent on the realization of the signal. We suppose that μ is large enough to ensure that it is optimal for the AA to run an investigation with probability one after receiving a good signal even when firms do not report information.[23] When instead the signal is bad, the AA carries out an investigation with probability σ. Therefore, the investigation policy boils down to choosing σ, which can be interpreted as the strategy of bluff. We assume that the AA can credibly commit itself about σ in stage 0, and stick to this investigation policy afterwards.

When the signal is public, cartel members will not report information if the AA launches an investigation after having received a bad signal, since they do not face any risk of conviction. When instead the signal is privately observed by the AA, there is scope for bluffing – i.e. choosing $\sigma > 0$ – as firms may fear that the investigation could be successful.

Firms. Firms decide whether to compete or collude. Collusion is sustainable if the expected value of future collusion exceeds the gains from deviating. In case of multiple sustainable collusive strategies, we assume that firms select the Pareto-dominant collusive strategy – i.e., the most profitable one.

Let us make some preliminary observations: first, since the investigation policy is stationary and the fine is independent on the duration of collusion, if collusion is profitable, then the best collusive strategy consists in colluding in every period until the cartel is condemned. Second, denouncing the cartel with positive probability before an investigation cannot be an optimal collusive strategy. If the collusive strategy prescribes to a firm to report before an investigation, the continuation value of the collusion is zero since the cartel will be shut down forever. Firms prefer therefore to deviate and compete rather than collude.[24] In contrast, an optimal collusive strategy may prescribe to report in case of investigation. However, it can be profitable to report only if the leniency rate is positive. Consequently, if the AA does not offer *post-investigation* leniency – i.e., if $q = 0$ – the most profitable collusive strategy is to "collude and remain silent". When $q > 0$, the optimal reporting strategy is necessarily symmetric since a firm is worse-off being silent whenever at least one other firm reports; therefore, it suffices to consider two collusive strategies: "collude and remain silent" and "collude and report in case of investigation".

In order to be sustainable, these collusive strategies must resist unilateral deviations on the market. The strategy "collude and remain silent" must moreover be incentive-

[22]However, it is important to stress that non stationary strategies are theoretically very powerful in deterring cartels. Frezal (2006) shows that a non-recurrent high probability of conviction better deter collusion than constant low average controls.

[23]For lower values of μ, the AA does not open any investigation in the absence of leniency – i.e., we are in a "Laissez-faire" regime.

[24]Mixing with private lotteries between reporting and not reporting before an investigation also requires the continuation value of the collusion to be zero, and firms prefer again to deviate and compete. Mixing with public lotteries could be sustainable, but collude and not report before an investigation is then *a fortiori* sustainable and more profitable.

compatible, that is, robust to unilateral reporting deviations: no firm should gain by reporting in case of investigation when the other firms remain silent. Therefore, firms choose to "collude and remain silent" instead of "collude and report in case of investigation" only if it is both more profitable and incentive-compatible.

Let us denote by γ, the probability that at least one firm reports information in case of investigation,[25] by ϕ, the conviction rate faced by firms when they collude and by $V(\sigma, \gamma, q)$, the value of collusion.

When firms collude in an industry, the AA runs an investigation with probability $\psi + (1-\psi)\sigma$. Either at least one firm reports, in which case the cartel is condemned with certainty, or no firm reports and the cartel is condemned only if the investigation is successful – i.e. with probability $\psi\mu$. Therefore, ϕ is:

$$\phi(\sigma, \gamma) = (\psi + (1-\psi)\sigma)\gamma + \psi(1-\gamma)\mu$$

$\phi(.,.)$ is strictly increasing in γ, increasing in σ (strictly if $\gamma > 0$) and lies between $\phi(0,0) = \psi\mu$ and $\phi(1,1) = 1$. Because firms are forced to compete once condemned, it follows that the value of collusion solves $V = \Pi^{Col} + \phi(\sigma,\gamma)(\frac{\delta\Pi^C}{1-\delta} - (1-q)F) + (1-\phi(\sigma,\gamma))\delta V$, that is:

$$V(\sigma, \gamma, q) = \frac{\Pi^{Col} + \phi(\sigma,\gamma)(\frac{\delta\Pi^C}{1-\delta} - (1-q)F)}{1 - \delta(1-\phi(\sigma,\gamma))}$$

Lemma 1. *$V(\sigma, \gamma, q)$ is (i) strictly decreasing in γ, (ii) decreasing in σ (strictly so for $\gamma > 0$) and (iii) strictly increasing in q.*

Proof. See Appendix. □

Let us denote by V_D, the value of the optimal deviating strategy. If one firm deviates, it obtains $\Pi^D > \Pi^{Col}$ but its continuation profit is $\frac{\delta\Pi^C}{1-\delta}$ since it will be punished by reversal to the minmax. As a deviating firm still faces a fine, the strategy "deviate on the market and simultaneously report *pre-investigation*" constitutes the optimal strategy if $q_0 > 1 - \phi(\sigma, \gamma)$. Since rewards are forbidden, offering full amnesty in case of pre-investigation reports is then always optimal ($q_0 = 1$), as this maximizes the incentives to deviate. The optimal deviating strategy has then value $V_D = \Pi^D + \frac{\delta\Pi^C}{1-\delta}$. Observe that restricting *pre-investigation* leniency to the first informant has no impact here. In the literature, limiting leniency to the first confessor prevents collusive firms from reporting in each period in order to protect themselves from fines (Spagnolo (2004), Chen and Rey (2007)). In our model, however, firms are forced to compete once condemned, which *de facto* deter firms from colluding and reporting information in each period.

[25] As already mentioned, cartel members will either all report or all remain silent in case of investigation – i.e., either $\gamma = 1$ or $\gamma = 0$.

2.4 Welfare

The AA is benevolent and maximizes total welfare,[26] or equivalently minimizes the social cost of collusion. Society incurs a per-period deadweight loss $L > 0$ when firms collude. For notational convenience, the society has the same discount factor δ as firms. The cost of carrying out an investigation is $c \geq 0$.

Firms collude in an industry if $V_D \leq V(\sigma, \gamma, q)$.[27] Gains from deviating are distributed across industries according to the cumulative distribution function G. Hence, $G(V(\sigma, \gamma, q))$ denotes the initial proportion of collusive industries in the economy. We are now able to write the social cost of collusion in the economy, C, which is such that:

$$C = G(V(\sigma, \gamma, q))\hat{C}$$

where $\hat{C}$ denotes the social cost of a cartel, when it is formed, and is such that:

$$\hat{C} = L + (\psi + (1 - \psi)\sigma)c + \delta(1 - \phi(\sigma, \gamma))\hat{C}$$

and thus:

$$\hat{C} = \hat{C}(\sigma, \gamma) \equiv \frac{L + (\psi + (1 - \psi)\sigma)c}{1 - \delta(1 - \phi(\sigma, \gamma))}$$

When firms collude, society incurs the loss L. The AA opens an investigation with probability $\psi + (1 - \psi)\sigma$, which allows to convict cartel members with probability $\phi(\sigma, \gamma)$. When condemned, firms are forced to compete which is the efficient social market behavior. Otherwise, society incurs the social cost of the cartel the following period.

An antitrust policy has a positive effect on cartel deterrence if it reduces the proportion of collusive industries. It has a positive effect on cartel desistance if it reduces the social cost of a cartel (denoted by $\hat{C}$).

3 Optimal Policy under Transparent Procedures

We proceed by backward induction. First, we determine, depending on the antitrust policy, whether firms choose to "collude and report in case of investigation", to "collude and be silent" or to compete. Then, we infer the optimal antitrust policy.

As already mentioned, when cartel members observe the AA's signal, they will never report if the AA receives a bad signal and thus the AA will never open an investigation in that case – i.e., σ=0. In contrast, cartel members may want to apply for leniency when the AA opens an investigation after receiving a good signal, since they do face a risk of being condemned. They are more likely to do so when (i) the risk of conviction μ ("the stick") is high; and: (ii) the leniency rate q ("the carrot") is high.

[26]We treat the fine as a transfer from the firms to the AA which thus does not affect welfare. The collected fines could however enter the objective function when the AA faces a budget constraint. The European Commission indeed argues that the penalties paid go to the Community budget and, therefore, contribute to finance the European Union.

[27]We implicitly assume here that collusion arises whenever it is sustainable, although competition remains an equilibrium even when collusion is sustainable.

"Collude and report in case of investigation" (R). When the AA runs an investigation after receiving a good signal and firms report, the cartel is condemned with probability 1 and not only with probability μ. From an *ex ante* perspective, the (expected) conviction rate is therefore $\phi(0,1) = \psi$, the AA's probability to receive a good signal. If leniency is granted to all informants, each collusive firm pays the reduced fine $(1-q)F$ when convicted. Therefore, the value of the collusion, V_B^R (where B stands for Benchmark), equals:

$$V_B^R(q) = V(0,1,q) = \frac{\Pi^{Col} + \phi(0,1)(\frac{\delta\Pi^C}{1-\delta} - (1-q)F)}{1-\delta(1-\phi(0,1))}$$

If instead leniency is granted only to the first informant (FI rule), the leniency rate faced by each firm is $\frac{q}{N}$, and the value of the collusion, $V_{B,FI}^R(q)$, equals $V_B^R(\frac{q}{N})$.

"Collude and be silent" (S). If all firms choose to remain silent when the AA carries out an investigation, the value of collusion, V^S, is:

$$V^S = V(0,0,q) = \frac{\Pi^{Col} + \phi(0,0)(\frac{\delta\Pi^C}{1-\delta} - F)}{1-\delta(1-\phi(0,0))}$$

The cartel is dismantled only if the AA after receiving a good signal succeeds in finding out hard evidence of collusion during the investigation. The conviction rate is then $\phi(0,0) = \psi\mu$. When convicted, firms pay the full fine F. As already mentioned, the collusive path "collude and be silent" faces an incentive-compatibility (IC_B) constraint: no firm should gain by instead reporting information when an investigation is ongoing – which is the case if:

$$\mu(\frac{\delta\Pi^C}{1-\delta} - F) + (1-\mu)\delta V^S \geq \frac{\delta\Pi^C}{1-\delta} - (1-q)F \qquad (IC_B)$$

If firms stick to the path "collude and be silent", either the investigation is successful with probability μ in which case cartel members must pay F and are forced to compete on the market or the investigation fails with probability $(1-\mu)$ and cartel members' discounted continuation payoffs are δV^S. If instead one firm betrays the cartel by unilaterally deciding to report, it pays only a reduced fine $(1-q)F$. This is independent on whether the AA implements or not a FI rule.

As already mentioned, firms choose to "collude and be silent" instead of "collude and report in case of investigation" only if it is both incentive-compatible and more profitable. Lemma 2 derives the firms' decisions in function of the AA's leniency policy.

Lemma 2. *There exists a threshold,* $q_\mu \equiv (1-\mu)\frac{\delta(\Pi^{Col}-\Pi^C)+(1-\delta)F}{(1-\delta)F+\mu\psi\delta F}$*, such that, provided that collusion is sustainable:*

for $q < q_\mu$*, firms collude and remain silent;*

for $q > q_\mu$*, firms collude and report in case of investigation;*

for $q = q_\mu$*, firms are indifferent between the two collusive strategies when leniency is granted to all informants. Under a FI rule, firms collude and remain silent.*

Proof. If leniency is granted to all informants, firms choose to "collude and be silent" instead of "collude and report in case of investigation" if and only if $V^S > V_B^R(q)$ and the (IC_B) constraint is satisfied. If the AA adopts a FI rule, firms choose to "collude and be silent" instead of "collude and report in case of investigation" if and only if $V^S > V_{B,FI}^R(q)$ and the (IC_B) constraint is satisfied.

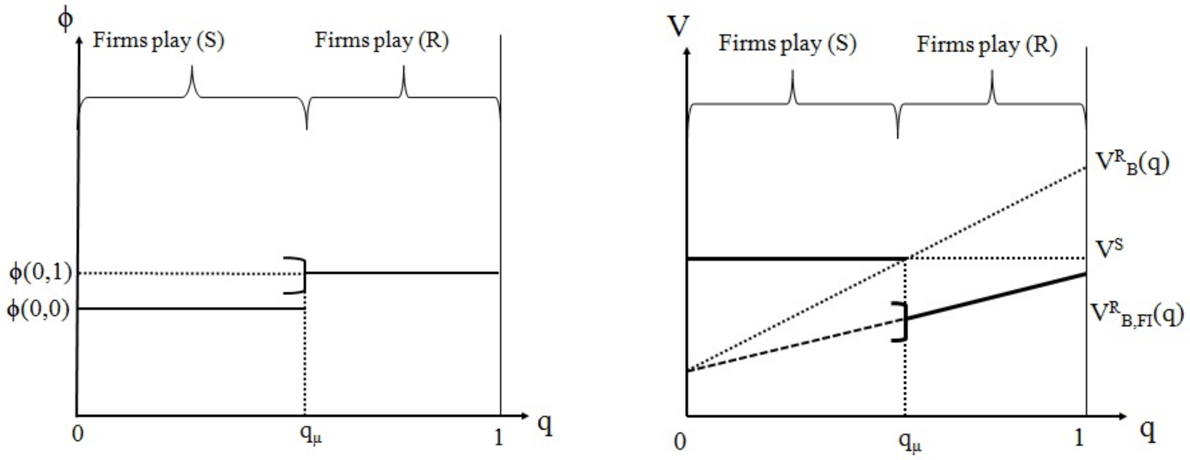
First, let us show that the (IC_B) constraint is equivalent to $V^S \geq V_B^R(q)$. Let us multiply by ψ and add Π^{Col} on both sides of the (IC_B) constraint. We obtain:

$$\Pi^{Col} + \psi\mu(\frac{\delta\Pi^C}{1-\delta} - F) + \psi(1-\mu)\delta V^S \geq \Pi^{Col} + \psi(\frac{\delta\Pi^C}{1-\delta} - (1-q)F)$$

Because $V^S = \Pi^{Col} + \psi\mu(\frac{\delta\Pi^C}{1-\delta} - F) + (1-\psi\mu)\delta V^S$, it follows that the (IC_B) constraint is equivalent to $(1-\delta(1-\psi))V^S \geq \Pi^{Col} + \psi(\frac{\delta\Pi^C}{1-\delta} - (1-q)F)$, and thus to $V^S \geq V_B^R(q)$. Second, simple computations show that $V^S \geq V_B^R(q)$ if and only if $q \leq q_\mu$. Third, observe that $V_B^R(q) \geq V_{B,FI}^R(q)$ (strictly so for $q > 0$).

It follows that if $q > q_\mu$, the (IC_B) constraint is not satisfied and cartel members choose to report in case of investigation (with or without a FI rule). If $q < q_\mu$, $V^S > V_B^R \geq V_{B,FI}^R(q)$: since (S) is incentive-compatible and more profitable than (R) (with or without a FI rule), cartel members choose to collude and be silent. Finally, if $q = q_\mu$, (S) is incentive-compatible, $V^S = V_B^R(q) > V_{B,FI}^R(q)$ and thus if leniency is granted to all informants, cartel members are indifferent between the two collusive strategies. Under a FI rule, firms collude and remain silent. □

q_μ is lower than 1 if μ is higher than a threshold $\underline{\mu} < 1$. Figure 2(a) represents the conviction rate and Figure 2(b) the equilibrium value of collusion in function of q for the case $\mu > \underline{\mu}$.[28]



(a) Conviction rate.

(b) Equilibrium value of collusion under a FI rule.

Figure 2: Benchmark

[28] On Figure 2(b), $V_{B,FI}^R(1)$ is either below or above V^S.

The optimal antitrust policy consists in choosing the leniency rate q and the informant rule (either the all informant or the FI rule) which minimize the social cost of collusion C.

Desistance. Cartel desistance is enhanced when firms report information, since in that case, conviction is obtained for sure during an investigation instead of being uncertain. The AA has to set the leniency rate above q_μ in order to force cartel members to report in case of investigation. When $\mu < \underline{\mu}$, it is however impossible to induce reporting if rewards are ruled out (i.e., if $q \leq 1$).[29] For the rest of the paper, we assume $\mu \geq \underline{\mu}$. Introducing a leniency rate $q > q_\mu$ suffices to optimize desistance,[30] and raises the conviction rate from $\phi(0,0)$ to $\phi(0,1)$.

Deterrence. We mentioned that restricting *pre-investigation* leniency to the first informant has no impact in our model. This is not true for *post-investigation* leniency. When $q > q_\mu$, a FI rule reduces the profitability of "collude and report in case of investigation" strategies from $V_B^R(q)$ to $V_{B,FI}^R(q)$ and therefore it should be preferred to an *all informant* rule. When leniency is given to all informants, firms report information only if it is profitable for the cartel as a whole to do so ((R) is played instead of (S) only if $V_B^R(q) > V^S$). By introducing a FI rule, the AA targets the fundamental weakness of the cartel, namely its internal cohesion. As a result, there is a discontinuity in the value of the collusion around q_μ: for $\tilde{q}$ just above q_μ, cartel members would be collectively better off by all remaining silent ($V^S > V_{B,FI}^R(\tilde{q})$). However, in that case, each firm is willing to betray the cartel by reporting when the other firms remain silent ($V_B^R(\tilde{q}) > V^S$). (S) is therefore not incentive-compatible and firms are forced to play a less profitable collusive strategy, namely (R).

The value of the collusion is minimized when the AA implements a FI rule and sets q just above q_μ (see Figure 2(b)). Offering more leniency is pro-collusive: this reduces expected sanctions without increasing any further the conviction rate, which mechanically raises the value of collusion.

Choosing q just above q_μ and implementing a FI rule optimize both cartel desistance and cartel deterrence and thus form the optimal antitrust policy. Proposition 1 summarizes the analysis:

Proposition 1 (Public signals)**. *Leniency policy.*** *The optimal leniency rate q^* is just above q_μ.*

Welfare. *Introducing post-investigation leniency is desirable both from a deterrence and a desistance perspective. The initial proportion of collusive industries drops from $G(V^S)$ to $G(V_{B,FI}^R(q^*))$ under a FI rule and the conviction rate increases from $\phi(0,0)$ to $\phi(0,1)$.*

[29] Obviously if rewards were allowed, reporting could be induced for any value of μ.

[30] Formally, optimizing desistance in the benchmark requires to minimize $\hat{C}(0,\gamma)$. As $\hat{C}(0,\gamma)$ is decreasing in γ, desistance is optimized when cartel members report information in case of an investigation. A corollary is that the choice of the informant rule plays no role from a desistance perspective.

4 Optimal Policy under Prosecutorial Discretion

Suppose now that firms do not observe the signal of the AA. When the signal is bad, the AA has no chance to condemn the cartel through its own investigations. Still, the AA may want to run an investigation in the hope that cartel members will denounce themselves the cartel.

As before, we proceed by backward induction and characterize the optimal antitrust policy when the AA can commit itself to a pre-specified investigation policy σ. If cartel members report in case of an investigation, "bluffing" – that is, choosing $\sigma > 0$ – enhances both cartel desistance and cartel deterrence. However, increasing σ has a shadow cost: it dilutes the risk of conviction if cartel members remain silent. By Bayes rule, the probability of prosecutorial success in case of an investigation equals $\frac{\psi\mu}{\psi+(1-\psi)\sigma}$, which is decreasing in σ. As we will see, because of this *dilution* effect, the optimal investigation policy σ^* is interior, so as to keep inducing cartel members to report.

"Collude and report in case of investigation" (R). When firms do not observe the AA's signal and report in case of investigation, they are condemned even when the AA received a bad signal. The conviction rate is therefore $\phi(\sigma, 1) = \psi + (1-\psi)\sigma$. If leniency is granted to all informants, the value of the collusion, $V^R(\sigma, q)$, is then:

$$V^R(\sigma, q) = V(\sigma, 1, q) = \frac{\Pi^{Col} + \phi(\sigma, 1)(\frac{\delta\Pi^C}{1-\delta} - (1-q)F)}{1 - \delta(1 - \phi(\sigma, 1))}$$

If instead the AA implements a FI rule, the value of collusion, $V^R_{FI}(\sigma, q)$, equals $V^R(\sigma, \frac{q}{N})$.

"Collude and be silent" (S). The value of the collusion remains V^S because the AA can find hard evidence only after receiving a good signal. (S) is again subject to an incentive-compatibility (IC) constraint: no firm should be willing to betray the cartel by reporting during an investigation, which is the case if:

$$(1 - \frac{\psi\mu}{\psi + (1-\psi)\sigma})\delta V^S + \frac{\psi\mu}{\psi + (1-\psi)\sigma}(\frac{\delta\Pi^C}{1-\delta} - F) \geq \frac{\delta\Pi^C}{1-\delta} - (1-q)F \qquad \text{(IC)}$$

The (IC) constraint is equivalent to:[31]

$$V^S \geq V^R(\sigma, q)$$

For $q \leq q_\mu$, $V^S \geq V^R(0, q)$ and thus cartel members do not report information in the absence of bluff (see the benchmark case). As $V^R(\sigma, q)$ is decreasing in σ, they will not report *a fortiori* when the AA chooses $\sigma > 0$.

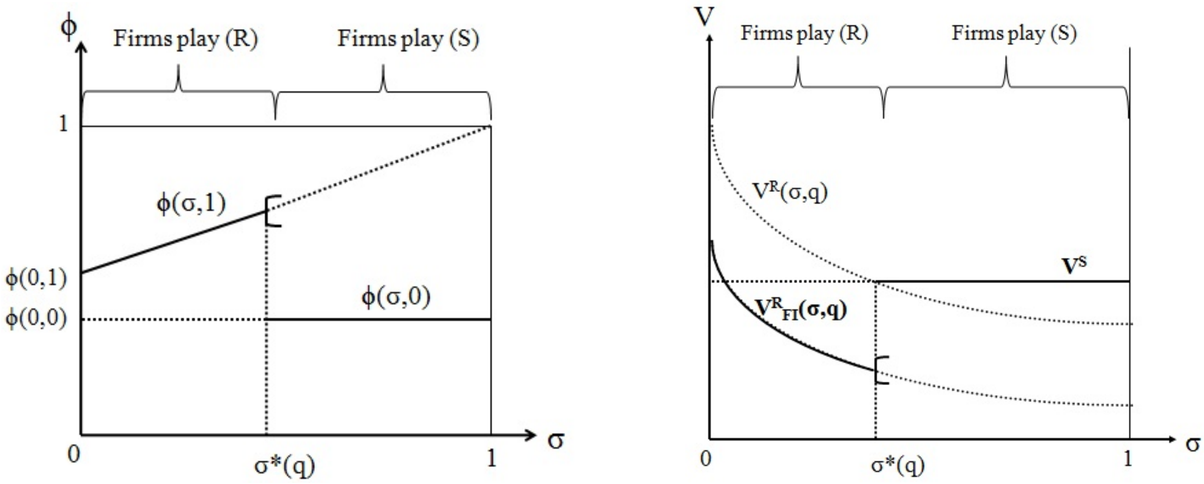
Suppose now that $q > q_\mu$. In that case, $V^R(0, q)$ is higher than V^S. Observe also that $V^R(1, q) = \Pi^{Col} + \frac{\delta\Pi^C}{1-\delta} - (1-q)F$, which is lower than $V^D = \Pi^D + \frac{\delta\Pi^C}{1-\delta}$, and thus we have $V^R(1, q) < V^S$ when $V^S \geq V^D$. We focus on the case $V^S \geq V^D$ since for $V^S < V^D$, collusion is deterred even in the absence of *post-investigation* leniency. As $V^R(\sigma, q)$ is

[31] To show the equivalence, it suffices to follow the same computations done in lemma 2.

decreasing in σ, for $q > q_\mu$, it follows that there exists a threshold $\sigma^*(q) \in (0,1)$ such that $V^S = V^R(\sigma^*(q), q)$. For $\sigma < \sigma^*(q)$, $V^S < V^R(\sigma, q)$ and thus (S) is not incentive-compatible. For $\sigma \geq \sigma^*(q)$, cartel members remain silent as (S) is incentive-compatible and more profitable than (R) (with or without a FI rule since $V^S \geq V^R(\sigma, q)$ implies $V^S > V^R_{FI}(\sigma, q)$).[32] Lemma 3 summarizes our analysis.

Lemma 3. *Provided that collusion is sustainable,*
for $q \leq q_\mu$, $\forall \sigma$, firms collude and remain silent;
for $q > q_\mu$,
if $\sigma < \sigma^*(q)$, firms collude and report in case of investigation;
if $\sigma > \sigma^*(q)$, firms collude and remain silent;
if $\sigma = \sigma^*(q)$, firms are indifferent between the two collusive strategies when leniency is granted to all informants. Under a FI rule, firms collude and remain silent.

Figure 3(a) represents the conviction rate and Figure 3(b) the equilibrium value of collusion as a function of σ when $q > q_\mu$.[33]



(a) Conviction rate.

(b) Equilibrium value of collusion under a FI rule.

Figure 3

The optimal antitrust policy consists in choosing the leniency rate q, the informant rule (all informant or FI rule) and the investigation policy σ which minimize the social cost of collusion C.

Desistance. Formally, optimizing desistance requires to minimize $\hat{C}(\sigma, \gamma)$, where γ equals either 0 or 1. It is easy to show that $\hat{C}(\sigma, 0)$ is increasing in σ, and $\hat{C}(\sigma, 1)$ is

[32] To be more precise, when $\sigma = \sigma^*(q)$ and leniency is granted to all informants, cartel members are indifferent between "collude and report in case of investigation" and "collude and remain silent".

[33] On Figure 3(b), $V^R_{FI}(0, q)$ is either below or above V^S.

decreasing in σ.[34] Moreover, $\hat{C}(0,1) < \hat{C}(0,0)$. Therefore, $\forall\ \sigma$ and $\tilde{\sigma}$, $\hat{C}(\sigma,1) < \hat{C}(\tilde{\sigma},0)$. It follows that optimizing desistance boils down to ensure that cartel members report in case of investigation ($\gamma = 1$), and to maximize σ under this constraint.

For $q \leq q_\mu$, cartel members remain silent in case of investigation (see Lemma 3) and therefore, $\hat{C}$ is minimized for $\sigma = 0$.

For $q > q_\mu$, cartel members report in case of investigation only if $\sigma < \sigma^*(q)$ (see Lemma 3) and thus, desistance is optimized when the AA chooses σ just below $\sigma^*(q)$. Intuitively, if the AA chooses σ low enough – i.e., below the threshold $\sigma^*(q)$ – it is likely to have received a good signal when it launches an investigation, consequently firms prefer to report. In contrast, when the AA chooses σ above $\sigma^*(q)$, the risk of conviction is too low to induce firms to denounce the cartel. Firms report information only if they perceive a significant risk than the AA will condemn them in case of an investigation; by bluffing, the AA dilutes this risk, possibly to the point of discouraging leniency applications.

Optimizing desistance turns out to be equivalent to maximizing the conviction rate (see Figure 3(a)). If the AA chooses σ above $\sigma^*(q)$, firms remain silent during investigations and the conviction rate drops to $\phi(0,0)$. Therefore, the AA is better off by choosing $\sigma = 0$ (as in the benchmark case) than choosing σ above $\sigma^*(q)$. Opening investigations too frequently after receiving bad signals penalizes desistance because it creates a negative externality on the efficiency of investigations launched after receiving good signals by discouraging cartel members from reporting information.[35]

Deterrence. The increase in the conviction rate is also beneficial in terms of deterrence. When the AA adopts a FI rule, for σ just below $\sigma^*(q)$, cartel members would be collectively better off by remaining silent in case of investigation. However, this is again not incentive-compatible and thus cartel members are forced to report, which materializes *ex ante* into a lower (expected) value of collusion (see Figure 3(b)).

The following proposition characterizes the optimal cartel policy.

Proposition 2 (Private signals)**.** ***Leniency policy.*** *It is optimal to grant full amnesty ($q = 1$).*

Investigation policy. *The optimal investigation policy is to fix σ just below $\sigma^*(1)$.*
Welfare. *Bluffing is welfare-enhancing. The initial proportion of collusive industries, here equal to $G(V^R_{FI}(\sigma^*(1),1))$ under a FI rule, is lower and the conviction rate, here equal to $\phi(\sigma^*(1),1)$, is higher compared to the benchmark.*

Proof. See Appendix. □

Increasing the leniency rate allows the AA to open more investigations while still ensuring that firms report, which enhances desistance ($\sigma^*(q)$ is increasing in q). Deterrence is simultaneously improved because the value of the collusion $V^R_{FI}(\sigma^*(q),q)$ is decreasing

[34] For $\hat{C}(\sigma,1)$ to be decreasing in σ, we have to assume that $c < \frac{\delta L}{1-\delta}$ – i.e., the social gain of condemning an existing cartel outweighs the cost of an investigation.

[35] It is also harmful because the AA pays the cost c when it opens an investigation with a bad signal without any benefit since cartel members do not report. Observe also that it is not optimal to open an investigation in every period even in the case where $c = 0$ – that is, when an investigation is costless.

in q. Intuitively, the increase in the conviction rate outweighs the pro-collusive effect of offering more leniency when the AA adopts a FI rule.[36] The leniency policy not only triggers applications as in the benchmark case but it also gives more room for bluffing. This second effect explains why full amnesty is optimal here.[37]

Proposition 3 (Comparative statics)**.** *Changes in the parameters have the following effects on the probability of bluff and on welfare:*

Increase in	Effect on	
	Probability of bluff $\sigma^*(1)$	Welfare
Private gain from collusion, $\Pi^{Col} - \Pi^C$	*Lower*	*Lower*
Social loss from collusion, L	*No effect*	*Lower*
Fine, F	*Higher*	*Higher*
Probability to have initial evidence, ψ	*Higher*	*Higher*
Efficiency of investigations, μ	*Higher*	*Higher*

As usual, a higher stake of collusion tilts the balance in favor of the cartel and makes prosecution more difficult. In contrast, a more generous carrot (i.e., a higher q) or a harsher stick (i.e., a higher fine F, a higher μ or a higher ψ) reinforces firms' incentives to betray the cartel. In our setting, this enables the AA to raise the probability of bluff, which has a positive effect on welfare.[38]

Comparative statics with respect to ψ confirm the complementary role of individual leniency programs and whistleblowing schemes. Firms are more prone to report when the AA is more likely to be informed by third parties about their illegal activities.

5 The Single Informant rule

The AA can do better than implementing a FI rule. Intuitively, an optimal informant rule should destabilize the collusive path (S) while minimizing the reduction in fines imposed on cartel members.

Let us allow the leniency rate to be fully flexible with respect to the number of informants. A leniency scheme is a N-tuple $Q = (q_1, \ldots, q_N)$ where $q_l \in [0, 1]$ for $l \in \{1, \ldots, N\}$; if the AA receives l leniency applications, each informant is eligible to the leniency rate q_l. Offering the leniency rate q to all informants is equivalent to the

[36] When leniency is granted to all informants, both effects exactly compensate each other. Formally, $V^R(\sigma^*(q), q)$ is constant in q and equals V^S.

[37] Again, rewards would raise further the probability of bluff which is desirable both in terms of desistance and deterrence. In particular, if the AA offers the reward $\tilde{q} > 1$ such that $\sigma^*(\tilde{q}) = 1$, it can bluff with probability one while still ensuring that cartel members report. When the leniency scheme is well-designed, rewards guarantee that collusion is deterred at no cost in all industries. Observe that deterrence here is based on *post-investigation* rewards whereas Spagnolo (2004)'s result rests on *pre-investigation* rewards (V_D can be made arbitrarily large by offering rewards).

[38] A lower $\Pi^{Col} - \Pi^C$, a higher F or a higher ψ, by directly decreasing the value of collusion, have also a trivial positive effect on welfare.

leniency scheme $(q, \ldots, q)$ whereas adopting a FI rule boils down to offer the leniency scheme $(q, \frac{q}{2}, \ldots, \frac{q}{N})$.

The (IC) constraint rewrites $V^S \geq V^R(\sigma, q_1)$. It is easy to see that the optimal leniency scheme imposes $q_1^* = 1$ and q_N^* arbitrarily close to 0;[39] q_1^* maximizes the internal conflict of interest between cartel members (formally, this tightens the (IC) constraint) and q_N^* minimizes the value of the "collude and report in case of investigation" strategy. The optimal leniency scheme involves a *single informant* rule (denoted hereafter SI rule), that is, amnesty should be given only if a unique cartel member reports information.

When the AA adopts a SI rule, it wins on both counts: firms are forced to play (R) ((S) is not robust to single reporting deviations when the AA sticks to σ just below $\sigma^*(1)$ and offers $q_1^* = 1$) and they end up paying the full fine. It follows that choosing to implement a SI rule instead of a FI rule enhances deterrence (both rules have the same effect in terms of desistance). The initial proportion of collusive industries drops to $G(V(\sigma^*(1), 1, 0)) < G(V_{FI}^R(\sigma^*(1), 1))$.[40]

The following table describes the optimal leniency scheme and welfare when the AA is allowed to adopt the SI rule.

	No post-investigation leniency		**Post-investigation leniency**		
			Public signals (benchmark)		**Private signals**
Optimal leniency rate	Immaterial		Any q above q_μ		$q = 1$
Optimal informant rule	Immaterial		SI rule		SI rule
Deterrence	$V(0,0,0)$	$>$	$V(0,1,0)$	$>$	$V(\sigma^*(1),1,0)$
Desistance (conviction rate)	$\phi(0,0)$	$<$	$\phi(0,1)$	$<$	$\phi(\sigma^*(1),1)$

Here, desistance and deterrence objectives are aligned, a main difference with Motta and Polo (2003) where the leniency policy enhances desistance but harms deterrence.

6 Policy Implications

We discuss here some policy implications of our model.

Real world leniency policy. In the benchmark case, when the AA implements a FI rule, the optimal leniency rate tends to zero if μ tends to one (see Lemma 2). Offering leniency in this case would be pro-collusive. This is the standard argument for refusing to

[39] q_N^* must be positive to ensure that reporting is a (strictly) dominant strategy. Observe that the optimal leniency scheme also requires q_l^* to be arbitrarily close to 0 for $l \in \{2, \ldots, N-1\}$ when the number of cartel members is initially unknown. Therefore, when at least two cartel members report, the effective reduction in the fine is arbitrarily close to 0. In order to facilitate the exposition, we assume it is equal to 0.

[40] The SI rule also outperforms the FI rule in the benchmark. The initial proportion of collusive industries equals $G(V(0,1,0))$ under the SI rule and $G(V(0,1,q_\mu))$ under the FI rule. Observe also that if the AA implements a SI rule, any q strictly above q_μ is optimal.

grant leniency when the probability to win the case in the absence of firms' confessions is already very large. This recommendation is implemented by antitrust authorities in the US and in Europe. Section B of the Corporate Leniency Policy grants post-investigation leniency to the first informant provided that the DoJ,

"at the time the corporation comes in, does not yet have evidence against the company that is likely to result in a sustainable conviction".

Similarly, the latest (European) Commission Notice (2006) on immunity from fines specifies that:

"In order to qualify [for reduction of a fine], an undertaking must provide the Commission with evidence of the alleged infringement which represents significant added value with respect to the evidence already in the Commission's possession".

Our analysis challenges this common view that leniency is necessarily pro-collusive when the risk of conviction is large. First, note that in the benchmark, if the AA implements a SI rule instead of a FI rule, offering full amnesty does not dilute deterrence even if μ is close to one. Again, this stresses that the design of the eligibility rules is crucial in determining the deterrence effect of leniency.

More importantly, and contrary to what the above motion suggests, it is optimal to maintain $q = 1$ even when μ is large, so as to implement the investigation policy $\sigma^*(1)$.

Cartel members' beliefs about the AA's ability to prosecute cartels. Antitrust authorities publicize their successes. One rationale is to induce cartel members to apply for leniency and to deter potential ones from forming new cartels.[41] Indeed, what matters is the firms' beliefs about prosecution efficiency (reflected here by ψ and μ) rather than its actual value. The importance of these beliefs has already been emphasized by the literature. Harrington (2006) for instance argues that:

"What can the antitrust authority do to move beliefs in this direction? It can advertise - remind firms that the antitrust authority is watching, that fellow cartel members may use the leniency program, that the antitrust authority has caught price-fixers. The antitrust authority can appear at trade association meetings, continually remind managers about the corporate leniency program, and advertise the programs successes."

The concern of pushing firms' beliefs upwards is also transparent in the rhetoric of antitrust authorities. Hammond (2001) declares:

"It is a far riskier proposition today to roll the dice and choose not to report antitrust wrongdoing than it used to be. The Division simply has more investigative tools in its

[41] Antitrust authorities insist on the important role of reporting past condemnations. Hammond (2004) claims that:

"[Of course], cultivating a fear of detection requires that an authority has a demonstrated track record of detecting cartels."

In the same vein, Barnett (2006) advocates that:

"antitrust enforcers should publicize their anti-cartel efforts in order to maximize deterrence".

arsenal than ever before. Our ability to discover and investigate antitrust offenses has dramatically improved based on a number of developments, including: (1) the high incidence of self reporting by amnesty applicants, as well as early cooperation from companies and individuals, even when amnesty is no longer available; (2) the Division's highly successful proactive use of amnesty, referred to as "Amnesty Plus," complemented by its proactive efforts to profile markets where cartel activity may be ongoing; and (3) the increased enforcement efforts and assistance provided by foreign antitrust authorities."

Our model highlights one potential advantage of moving firms' beliefs upwards. Suppose one firm believes that the AA receives a good signal with probability $\psi' > \psi$ instead of the actual prior ψ.[42] This could be due to AA's publicity, risk-aversion, or agency frictions.[43] Provided it is aware about it, the AA can raise the probability of bluff which enhances cartel desistance and deterrence. Note that it is enough to fool only a single firm about the risk of conviction in order to destabilize the cartel as a whole.

Finally, observe that a leniency policy can be useful in trying to fool firms about the actual risk of conviction, as it makes it more difficult to learn the efficiency of the AA's prosecution. Indeed, when one cartel member reports, other firms are not able to revise their beliefs about the underlying conviction rate, i.e. the probability of prosecutorial success in the absence of confessions.

Miscoordination among cartel members. By assuming that cartel members can coordinate themselves on the Pareto-dominant collusive path, we have chosen the *equilibrium selection* which is the most "favorable" to firms, and by the same token, the most "detrimental" to the AA. Even in this case, we have shown that bluffing is welfare-enhancing. If instead cartel members cannot perfectly coordinate their reporting decisions, the AA could raise the investigation policy σ above $\sigma^*(1)$ and still obtain confessions. In particular, when one firm believes that at least one other firm will apply for leniency, it reports information even when the AA chooses the investigation policy $\sigma = 1$.

Positive risk of conviction in case of a bad signal. Until now, we have assumed that the AA has no chance to find evidence when it opens an investigation after receiving a bad signal. Suppose instead that in such a case, the AA can find hard evidence with probability $\mu_L > 0$, and let us focus on the interesting case where the AA wants to open an investigation after receiving a bad signal even if cartel members choose not to report.[44] It follows that in the absence of leniency, when there is a cartel in an industry, the AA opens an investigation in every period.

When the signal is private information, the AA is actually better off lowering the probability to open an investigation in case of a bad signal, in order to induce cartel

[42]The same is true with respect to firms' beliefs about μ.

[43]The firm may fear than its employees are more likely to be informed about collusive practices and to whistle blow.

[44]A sufficient condition is that $c < \mu_L \frac{\delta L}{1-\delta}$. Opening an investigation after receiving a bad signal costs c and allows to find hard evidence with probability μ_L; the (discounted) gain for dismantling the cartel is $\frac{\delta L}{1-\delta}$. This is a sufficient but not a necessary condition as it does not take into account the positive effect of opening an investigation on cartel deterrence.

members to report information. Perhaps surprisingly, in that case the introduction of leniency – i.e., moving from no leniency to the optimal leniency scheme under prosecutorial discretion – raises the overall conviction rate and thus welfare but lowers the number of cartel cases, even in the short run.[45]

From an empirical perspective, an important corollary is that *antitrust activity* is not necessarily a good proxy for assessing the efficiency of the antitrust policy: our analysis shows that a drop in the number of cartel cases around the introduction of leniency may well correspond to an improvement of cartel policies.

Ex-post transparency as a commitment device. We assumed that the AA can commit to a given investigation policy. A potential tool to credibly commit is *ex post* transparency. In our case, the AA should report cartel cases where it refrained from opening (or postponed) an investigation due to the insufficiency of initial evidence against the cartel.[46]

***Single Informant* Rule.** Spagnolo (2007) discusses the objective of an optimal leniency program:

"*This means that a well-designed program must maximize incentives to betray the cartel by reporting important information to the Antitrust Authority, while at the same time limiting as much as possible the reduction in fines imposed on the whole cartel. This objective can be achieved by maximizing the benefits an individual cartel member can receive from reporting under the leniency program, but restricting such maximal benefit to one and only one reporting party, the first comer.*"

We fully agree with the diagnosis. However, our analysis challenges the optimal response: in order to minimize the reduction in fines imposed on the whole cartel, the SI rule outperforms the FI rule.

Observe that implementing the SI rule in the real-world would require (i) to offer leniency only during a limited duration and (ii) to enforce the privacy of leniency applications over this period. Note also that the success of the SI rule rests on the assumption that cartel members are forced to compete forever once condemned. When instead firms go on colluding after being condemned, the SI rule is equivalent to the FI rule: in both cases, when firms choose the collusive path "collude and report in every period", they will take turns for reporting and obtaining leniency.

7 Conclusive Remarks

The literature on leniency programs does not consider private information on the AA side. We have shown that taking it into account has important implications for leniency policies.

[45]That is, abstracting from the deterrence effect of leniency which also goes in the direction of reducing the number of cartel cases.

[46]Observe that firms can statistically infer the investigation policy of the AA directly from the number of cartel cases when they know ψ and the distribution of Π^D.

When it is privately informed about the strength of the case against a cartel, the AA may obtain confessions even when it opens an investigation knowing that it is unlikely to find hard evidence. However, the AA should carefully choose its investigation policy as opening investigations when the probability of prosecutorial success is low dilutes the average risk of conviction faced by cartel members and therefore lowers the likelihood of leniency applications. In this context, offering more leniency is desirable because it counterbalances the dilution in the risk of conviction, and thus allows the AA to open more successful investigations. As a result, the optimal leniency rate is the highest possible, in our case full amnesty.

The natural question is then whether the AA can simultaneously improve cartel deterrence by properly designing the leniency scheme. In this respect, we first confirm the advantage of restricting leniency to the first confessor, instead of granting leniency to all informants. Then, we derive the optimal leniency scheme when the AA is allowed to offer leniency rates contingent on the number of informants. The optimal scheme involves a single informant rule, that is, amnesty should be given only if a unique cartel member reports. When the AA adopts the single informant rule, amnesty is a lure, since all cartel members face the same unilateral incentives to cheat on the cartel. One interesting direction for future research would be to investigate the robustness of this single informant rule, for instance when there is asymmetry between cartel members.

Appendix

Proof of lemma 1.

$$(i)\ \frac{\partial V}{\partial \gamma} = \frac{\phi_2(\sigma,\gamma)(\delta(\Pi^C - \Pi^{Col}) - (1-\delta)(1-q)F)}{(1-\delta(1-\phi(\sigma,\gamma)))^2} < 0$$

$$(ii)\ \frac{\partial V}{\partial \sigma} = \frac{\phi_1(\sigma,\gamma)(\delta(\Pi^C - \Pi^{Col}) - (1-\delta)(1-q)F)}{(1-\delta(1-\phi(\sigma,\gamma)))^2} \leq 0$$

$$(iii)\ \frac{\partial V}{\partial q} = \frac{\phi(\sigma,\gamma)F}{1-\delta(1-\phi(\sigma,\gamma))} > 0$$

□

Proof of proposition 2. We showed that σ just below $\sigma^*(q)$ is optimal.

As $\sigma^*(q)$ is increasing in q, desistance is optimized for $q = 1$. Let us show that $V^R_{FI}(\sigma^*(q), q)$ is decreasing in q in order to prove that $q = 1$ is also optimal from a deterrence perspective.

After some straightforward manipulations, we can show that:

$$V^R_{FI}(\sigma^*(q), q) = V^R(\sigma^*(q), q) - \frac{\phi(\sigma^*(q), 1)\frac{N-1}{N}q}{1-\delta+\delta\phi(\sigma^*(q), 1)}$$

Take $q_1 > q_0$. By definition, $V^R(\sigma^*(q_1), q_1) = V^R(\sigma^*(q_0), q_0)$. It follows that $V^R_{FI}(\sigma^*(q_1), q_1) < V^R_{FI}(\sigma^*(q_0), q_0)$ is equivalent to:

$$\delta\phi(\sigma^*(q_1), 1)\phi(\sigma^*(q_0), 1)(q_0 - q_1) < (1-\delta)(\phi(\sigma^*(q_1), 1)q_1 - \phi(\sigma^*(q_0), 1)q_0)$$

The LHS is negative while the RHS is positive. Hence, $V^R_{FI}(\sigma^*(q), q)$ is decreasing in q. Q.E.D.

□

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