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Cartel stability and the Duration of Price Wars**

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Leniency Programs under Demand Uncertainty: Cartel Stability and the Duration of Price Wars

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Abstract

Leniency Programs reduce sanctions against cartel members that either report spontaneously the existence of the infringement or cooperate during the investigation and facilitate prosecution. This paper investigates the impact of leniency programs on cartel stability when demand is uncertain and firms cannot perfectly observe their rival's choices. We show that pre-investigation leniency may or may not be effective in destroying the cartel, but in neither case affects the duration of price wars. Post-investigation leniency may have ambiguous welfare effects, in affecting both cartel stability and price wars duration. LPs applying in situations where leniency is not urgently needed may be not only ineffective, but also welfare reducing. Hence, in markets where negative demand shocks are sufficiently frequent, leniency policies may produce undesirable effects.

JEL Classification: K21, L12, L41

Keywords: antitrust enforcement, collusion, leniency programs, price wars

1 Introduction

Leniency Programs (LPs) aim to improve cartel deterrence by offering fine reductions to cartel members that voluntarily self-report or cooperate during investigation. The objective of this paper is to examine the effect of LPs on collusion when demand is stochastic and firms cannot perfectly observe their rival's choices. It is shown that an LP may affect both, the duration of the competitive price wars which are necessary for cartel stability, and the levels of demand uncertainty under which collusion is viable.

While it is well known that no collusive agreement can be successful without the participating firms' willingness to credibly punish deviations, there are instances where extremely hard punishments may be counterproductive. Such is the case analyzed in Green and Porter (1984, GP hereafter) where in the presence of unexpected demand slumps it is preferable for cartel-participating firms unable to perfectly monitor each other's actions to adopt strategies that are more lenient than the so-called "grim" (or "trigger") strategy.¹ In the GP context, a firm observing low sales cannot distinguish whether they are due to a deliberate price cut by a rival, or simply to sluggish demand. Punishing to infinity destroys, potentially for no reason, an otherwise profitable cartel. At the same time, not punishing at all induces cheating on the cartel agreement with certainty. An intermediate solution is a strategy that calls for interrupting cooperation every time low sales are observed (independently of their origin), but only for a limited number of periods. GP shows that a long enough period of cooperation-interruption is sufficient to induce loyalty to the cartel agreement. This way, cooperation may be disrupted for a number of periods giving its place to price wars, but stays alive in the long run.

In this paper we consider a supergame in which firms choose between competing and colluding. The demand is stochastic and a low demand state occurs with positive probability, while each firm cannot perfectly observe the price set by the rival. We show that leaving the LP available after an inspection has already been launched (post-investigation leniency) may have ambiguous effects on collusion. When negative demand shocks are frequent, post-investigation leniency may a) reduce the duration of temporary competitive price wars, and b) enlarge the set of negative-

¹ "Grim" (or "trigger") strategies correspond to a commitment to maximum punishment in case of an observed (or suspected) deviation, triggering competition for an infinite number of periods.

demand-shock probabilities for which the collusive agreement is viable. In other words, introducing leniency may in some instances enhance, instead of undermining cartel stability. Cartel stability is more likely to be enhanced when negative-demand-shocks are expected to be frequent in the future, and the probability of conviction after investigation is already high. Our conclusion is that in such cases, fine reductions not only are of little help, but also have undesirable side-effects. On the contrary, when the probability of conviction is low, leniency policies always result in a welfare improvement.

The effect of LP on cartels is first examined in Motta and Polo (2003) which stresses the importance of post-investigation leniency. Spagnolo (2004) concludes that costless cartel deterrence can be achieved when the first informant is rewarded sufficiently. Chen and Rey (2013) shows that it is optimal to provide leniency post-investigation when conviction is not very likely without self-reporting. Studying empirically the effectiveness of the early European corporate LP, Brenner (2009) concludes it has not significantly affected cartel stability, eventually because of the weakness of the provided incentives.

The paper is organized as follows: The model is described and benchmark is set in section 2. Section 3 contains the solution of the model when post-investigation leniency is introduced. In section 4 the analysis is concluded.

2 The Model with pre-investigation LP (the benchmark case)

Two firms producing homogeneous products and competing in prices play a competition *vs.* collusion game in an infinite number of periods. They both have the same discount factor $\delta \in (0,1)$ and maximize the expected sum of their future discounted profits. During a single period, firm i 's profit, $i = 1, 2$, is

- π^C if both firms cooperate
- $\pi^D = 2\pi^C$ if firm i deviates from the collusive agreement while the other charges the collusive price
- 0 if firm i charges the collusive price while the other deviates or if both firms compete

Due to resource limitations the Antitrust Authority (AA) investigates the industry with probability $a \in (0,1)$. When the industry is investigated while cartelized each firm is convicted with probability $\rho \in (0,1)$. Conviction entails a monetary fine

$F = \mu\pi^j, j = D, C$. A LP offers a cartel participating firm the option to provide cartel-related information and/or evidence, in exchange to a reduction in its fine in case the cartel is finally convicted. The reduced fine for reporting firms is $\gamma\pi^j$, with $0 \leq \gamma < \mu$. The evidence about collusion can be used by the AA only for one period and firms cannot be convicted for past violations.

At the beginning of each period each firm decides whether to collude. If at least one firm refuses to collude, competition takes place at least up to the end of the period. Assuming that a cartel agreement is in effect, each firm chooses between staying loyal to the agreement and defecting from it. Under LP, the defecting firm can also opt for denouncing the cartel, which, in that case is convicted with probability 1. In this section we restrict this option to only before any investigation is opened, leaving the case where firms may benefit from fine reductions by reporting after an investigation is launched for the next section.

During each period the demand can be either zero with probability q or positive with probability $1 - q$. Firms can observe directly neither the demand state, nor the price set by their competitor. As a consequence, a firm observing zero profits at any period cannot be sure whether this is due to its rival's defection from the agreement, or simply to low demand. Since in an infinitely repeated game that firm is bound to experience zero profits at some point, it may not find it optimal to retaliate by reverting to competition forever. Instead, after observing its profits being zero, a firm interrupts cooperation during a finite number of T periods (punishment period), during which both firms compete before reverting again to collusion.² During the punishment phase, firms set their price equal to marginal cost, earning zero profits for T periods.³

² See also Tirole (1988) pp 262 on Green and Porter (1984)

³ Marginal cost pricing is the result of assuming price competition on homogeneous products. It must be stressed that none of these assumptions is crucial for our results, as our analysis is also robust in allowing for differentiated products and/or quantity competition. What is crucial is that in all cases, by looking at its own profits, a firm cannot make a perfect inference about the other firm's behavior. For instance, if we allow for differentiated products, a firm can always cheat and jam the signal to the other firm, provided that it does not reduce its price below a level that would cause its rival to make lower profits than under a low demand state. Such constrained cheating allows the eventual cheater to obtain an only temporary, instead of permanent, interruption of cooperation. Robustness in case of Cournot competition can be shown along a similar argument.

We consider that in order to solve the coordination problem, regarding the specification of the optimal collusive price or the conditions that trigger the temporary reversion to competition, a sort of communication between firms is necessary. As explained in Green and Porter (1984) “...in view of the relative complexity of the conduct to be specified by this particular equilibrium and of the need for close coordination among its participants, it seems natural to assume here that the equilibrium arises from an explicit agreement.” (Green and Porter, 1984, p.89, footnote 5). Since firms engage in a kind of communication, it is reasonable to assume that the estimation of q is common for both firms.

Each colluding firm facing the high demand state expects to earn the collusive profits and to pay the full fine in case of successful investigation. That firm keeps colluding for at least one additional period, as long as neither the collusive agreement is detected by the AA, nor a negative demand shock occurs. The observation of zero profits triggers reversion to Bertrand-Nash pricing for the T -period punishment phase, with return to cooperation afterwards. We denote this strategy as C. If the cartel is detected the AA monitors the industry for an infinite number of periods, forcing firms to earn zero profits. The value of C is therefore:

$$V^C = (1 - q)\pi^C(1 - a\rho\mu) + \delta V^C[(1 - a\rho)(1 - q) + q\delta^T]$$

yielding

$$V^C = \frac{(1 - q)\pi^C(1 - a\rho\mu)}{1 - (1 - a\rho)(1 - q)\delta - q\delta^{T+1}} \quad (1)$$

A defecting firm facing positive demand anticipates earning during the first period the entire monopoly profits $\pi^D = 2\pi^C$ reduced by the expected fine $a\rho\mu 2\pi^C$. Since the rival cannot distinguish between deliberate deviation and negative demand shock, competition takes again place during T periods. As always, cartel detection and punishment implies competition to infinity. Given the above, the value of secret undercutting is:

$$V^D = (1 - q)2\pi^C(1 - a\rho\mu) + [(1 - a\rho)(1 - q) + q]\delta^{T+1}V^C \quad (2)$$

No firm has incentive to undercut when

$$V^C \geq V^D \Leftrightarrow \delta^{T+1} \leq \frac{2\delta(1 - a\rho)(1 - q) - 1}{1 - a\rho - q(2 - a\rho)} \quad (3)$$

If the RHS of (3) is positive, then there exists a lower bound on T above which the inequality is satisfied. Necessary conditions for the RHS being positive are $\delta \geq$

$\frac{1}{2(1-a\rho)(1-q)}$, along with $q < \frac{1-a\rho}{2-a\rho}$.⁴ A sufficiently high probability of negative demand shock lowers the cost of immediate defection and makes collusion impossible to sustain. Note that for $T = 0$ collusion is never sustainable.

Taking logarithms of both sides of (3) and rearranging, yields

$$T \geq T_1 \equiv \frac{\ln \left[\frac{2\delta(1-a\rho)(1-q) - 1}{1-a\rho - q(2-a\rho)} \right]}{\ln \delta} - 1 \quad (3)$$

Since V^C decreases with T , firms benefit from choosing the shortest punishment period that secures the incentive constraint.

2.1 Pre-investigation leniency

Since reporting the cartel leads to conviction with certainty, following a firm's application for leniency, the competitive outcome prevails forever. In this case the reporting firm expects to earn $2\pi^C(1-\gamma)$ with probability $1-q$ and the competitive (zero) profits thereafter:

$$V^L = \frac{(1-q)2\pi^C(1-\gamma)}{1-q\delta^{T+1}} \quad (4)$$

The IC for cartel sustainability is $V^C \geq V^L$, which, using (4) and (1), implies

$$\delta^{T+1} \geq \frac{2(1-\gamma)[1-(1-a\rho)(1-q)\delta] - (1-a\rho\mu)}{q[2(1-\gamma) - (1-a\rho\mu)]} \quad (5)$$

Setting $q = 0$ yields the full information result where collusion is sustainable when the AA does not offer sufficient leniency, i.e. $\gamma \geq 1 - \frac{1-a\rho\mu}{2[1-\delta(1-a\rho)]}$. Under stochastic demand, the collusive strategy is superior when the necessary punishment period is short enough, i.e.:

$$T \leq T_2 \equiv \frac{\ln \left[\frac{2(1-\gamma)[1-(1-a\rho)(1-q)\delta] - (1-a\rho\mu)}{q[2(1-\gamma) - (1-a\rho\mu)]} \right]}{\ln \delta} - 1 \quad (5)$$

When $T_1 \leq T_2$ setting $T = T_1$ induces cartel behavior with the least punishment, therefore the LP is completely ineffective. This occurs when:

$$T_1 \leq T_2 \Leftrightarrow \gamma \geq \hat{\gamma} \equiv \frac{1 - 2\delta(1-a\rho)(1-q) + a\rho\mu(1-2\delta q)}{2[1-\delta + a\rho\delta(1-q)]} \quad (6)$$

Leniency destabilizes the cartel by making long punishment periods unattractive: facing a sufficiently long punishment period the prospective defector will opt for

⁴ Since the positive denominator is always larger than the numerator, the latter should be also positive.

reporting the cartel rather than waiting for the restoration of cooperation. Given that the current LP in the EU absolves the informant firm for the entirety of its corresponding fine, the following lemma states the effect of fully absolvent pre-investigation leniency on cartel stability:

Lemma 1. *Assuming that the demand is zero or positive with probability q and $1-q$ respectively, and that each firm cannot perfectly observe the price choices of the rival, the introduction of a fully absolvent LP: i) succeeds or fails to obstruct collusion depending on whether $q > \hat{q} \equiv \frac{2\delta(1-a\rho)-(1+a\rho\mu)}{2\delta[1-a\rho(1+\mu)]}$ or $q \leq \hat{q}$ respectively, ii) has no impact on the length of the punishment period.*

Proof

Combining (3') and (5'), cartel stability requires $T_1 \leq T \leq T_2$ which is impossible when $T_1 > T_2$. When $T_1 > T_2$ the introduction of LP destabilizes the existing cartel since for $T \geq T_1$, V^C is always inferior to V^L while a reduction of T below T_1 induces defection. On the contrary, if $T_1 \leq T_2$ setting $T = T_1$ allows firms to maintain collusive behavior with the least punishment, therefore the LP is completely ineffective. The latter happens if $\gamma \geq \hat{\gamma}$. A fully absolvent LP offers $\gamma = 0$, hence it is ineffective when $\hat{\gamma} \leq 0$. Solving for q , the latter yields $q \leq \hat{q} \equiv \frac{2\delta(1-a\rho)-(1+a\rho\mu)}{2\delta[1-a\rho(1+\mu)]}$. ■

When the probability of negative demand shocks is sufficiently high, firms find optimal to report the cartel because the expected loss of future earnings from the interruption of cooperation is not large enough. However, when q is low, both firms may not be willing to give up the opportunity for future cooperation, since the probability of positive future profits is high. A necessary condition for an LP with $\gamma = 0$ (full leniency) to be effective is $\hat{\gamma} > 0$, which implies

$$\mu > \hat{\mu} = \frac{2\delta(1-a\rho)(1-q) - 1}{a\rho(1-2\delta q)}$$

Hence, for LP to be effective the fine in case of conviction must be large enough.

Note that in case of certainty, i.e. when $q = 0$, the critical value of μ is $\frac{2\delta(1-a\rho)-1}{a\rho}$

which is always larger than $\hat{\mu}$. As q increases the collusive strategy becomes less attractive and a lower level of fines becomes sufficient to deter cartel activity. For any given level of fines, a higher value of q increases the value of $\hat{\gamma}$, indicating that in situations where the probability of low demand states is high, LPs providing moderate leniency are sufficient to destabilize the collusive agreement.

*A numerical example*⁵

Let us set the probability of detection and conviction, $a\rho = 0.12$. Letting also $\delta = 0.85$ and $\mu = 2$, an LP with full leniency ($\gamma = 0$) seems to be ineffective ($\hat{\gamma} < 0$) when the probability of negative demand shock is below 0.235. An increase of the discount factor expands the range of q for which LP is ineffective. For instance, when $\delta = 0.9$ full leniency is not sufficient for all $q < 0.3$. On the other hand, more severe enforcement results in a reduction of $\hat{q}$. For example, if $\mu = 2.5 \Leftrightarrow \hat{q} = 0.2$.

3 Allowing for post-investigation leniency

When firms can apply for leniency after an investigation has opened, an alternative collusive strategy arises for a colluding firm. This strategy, call it R, consists of maintaining cooperation as long as the cartel escapes the AA's attention, and reporting as soon as the cartel is targeted by an investigation, in order to benefit from reduction in eventual fines. Assume that the AA applies leniency according to the first informant rule, *i.e.*, the first firm that reports the collusive agreement receives a fine reduction while the other cartel participants pay the full fine, and let the reduced fine for the first informant be $\gamma^I \pi^m$, with $0 \leq \gamma^I < \mu$.⁶ We assume that, if both firms decide to report, each firm has a 0.5 probability to win the reporting race and pay the reduced fine. Given the above, the value of R is:

$$V^R = (1 - q) \left[(1 - a)(\pi^C + \delta V^R) + a\pi^C \left(1 - \frac{\gamma^I + \mu}{2} \right) \right] + q\delta^{T+1}V^R$$

which, after rearrangement yields

$$V^R = \frac{(1 - q)\pi^C \left(1 - a\frac{\gamma^I + \mu}{2} \right)}{1 - (1 - q)(1 - a)\delta - q\delta^{T+1}} \quad (7)$$

⁵ Using data from DoJ price-fixing cases, Bryant and Eckhart (1991) estimated the probability of cartel detection to be between 0.13 and 0.17 in a given year. Combe et al. (2008) estimated the same probability over a European sample to be around 0.13. Connor and Lande (2012) assessed that 0.2 to 0.28 of detected cartels are not convicted.

⁶ The relevant theoretical literature usually concludes in favor of the first informant rule. Spagnolo (2004) claims that only the first informant should be rewarded sufficiently. Harrington (2008) also supports that restricting leniency to the first reporting firm induces the “race to the courthouse” effect when the investigation has launched. Ishibashi and Shimizu (2010) shows that providing amnesty to later applicants is of no use.

In order to be adopted, strategy R must be incentive compatible in the sense that each firm prefers to report under investigation given that the other continues colluding, which implies:⁷

$$\pi^C(1 - \gamma^I) \geq \rho\pi^C(1 - \mu) + (1 - \rho)(\pi^C + \delta V^C) \quad (8)$$

Lemma 2 provides the condition under which firms choose to report under investigation, given that both collusive strategies, C and R, are sustainable:

Lemma 2. *For any level of forgiveness, after the opening of an investigation firms choose R instead of C when the punishment phase is long enough.*

Proof

Rearranging (8) yields $\delta^{T+1} \leq \frac{(\rho\mu - \gamma^I)[1 - \delta(1 - q)(1 - a\rho)] - \delta(1 - \rho)(1 - q)(1 - a\rho\mu)}{q(\rho\mu - \gamma^I)}$. ■

Furthermore, strategy R can be incentive compatible for any duration of the punishment phase, provided that the LP forgives a sufficient amount of the initial fine: setting $T = 0$ in (8) gives $\gamma^I \leq \frac{\rho\mu - \delta\{1 - q + \rho[\mu - 1 + q - a\mu(1 - q)]\}}{1 - \delta + a\delta\rho(1 - q)}$. Note that incentive compatibility of the alternative collusive strategy does not imply that R is more profitable than C. The profitability condition is stricter than the incentive compatibility constraint since the minimum T that renders (8) effective is always lower than the minimum T required for $V^R \geq V^C$ to hold:

$$V^R \geq V^C \Leftrightarrow T \geq T_5 \equiv \frac{\ln Z}{\ln \delta} - 1$$

where $Z = \frac{2\mu\rho - (\gamma^I + \mu) - \delta(1 - q)[2(1 + \rho(\mu - 1)) - a\rho(\mu - \gamma^I) - (\gamma^I + \mu)]}{q[2\mu\rho - (\gamma^I + \mu)]}$.

Since (8) is less strict than the profitability condition above, an amount of forgiveness that suffices to satisfy (8) may in some cases not be able to also render R more profitable than C. In those cases the situation resembles to a prisoners dilemma where each firm under investigation may find privately optimal to report, even if mutually keeping secrecy and sticking to collusion might have assured to both firms higher payoffs.

For the cartel to be sustainable as long as it escapes investigation, strategy R must be preferred to both, secret undercutting and pre-investigation reporting. Concerning the first, setting $V^R \geq V^D$ yields:

$$\delta^{T+1} \leq \frac{2(1 - 2a\rho\mu) + a(\gamma^I + \mu) - 4\delta(1 - a)(1 - q)(1 - a\rho\mu)}{2a\rho(1 - q) + a(\gamma^I + \mu)[1 - a\rho(1 - q)] - 2[1 - 2q(1 - a\rho\mu)]} \quad (9)$$

⁷ See also Sauvagnat (2014)

A deviation without reporting seems to be less attractive when the consequent competitive phase is expected to be long enough. Therefore, denoting as T_3 the minimum value of T for which (9) holds, the leniency-induced strategy of colluding until investigation and reporting afterwards dominates secret undercutting when $T \geq T_3$

In order for R to also dominate the strategy of reporting before investigation, it must be that $V^R \geq V^L$. Using (7) and (4), this implies:

$$\delta^{T+1} \geq \frac{2(1-2\gamma) + a(\gamma^I + \mu) - 4\delta(1-a)(1-q)(1-\gamma)}{q[2(1-2\gamma) + a(\gamma^I + \mu)]} \quad (10)$$

Since the cost of the definite collapse of the cartel decreases with T , the inequality above holds for short enough punishment period. We use T_4 to denote the maximum value of T that makes (10) hold.

Combining the above results, the following lemma provides the sustainability condition for strategy R:

Lemma 3. *Strategy R is sustainable when q is low enough, i.e. when*

$$q \leq \bar{q} \equiv \frac{(1-a\rho)[4\delta(1-a)(1-\gamma) - a(\gamma^I + \mu) - 2(1-2\gamma)]}{4(1-a)\delta[1-a\rho(1-\gamma+\mu)]}$$

Proof

Since sustainability implies that strategy R dominates both a) secret undercutting and b) pre-investigation reporting, it must be that $T_3 \leq T_4$. Setting the RHS of (9) to be larger than that of (10) and solving for q shows that the expression in the lemma is a necessary and sufficient condition for $T_3 \leq T_4$. ■

The intuition behind lemma 3 is similar to that of lemma 1: Any collusive strategy is more likely to be sustained when the probability of negative demand shocks is low, since firms cannot disregard the expected benefit stemming from cooperation in the future.

We need to define the level of q where T_1 and T_3 are equal: setting $T_1 = T_3$ and solving for q yields:

$$q = \tilde{q} \equiv \frac{(1-a\rho)[\mu(2\rho-1) + \delta(\mu-2 + \rho(2-(2-a)\mu)) - \gamma^I(1-\delta(1-a\rho))]}{\delta[\rho(a(2+3\mu-\rho(2+(2+a)\mu)) - \gamma^I(1-a\rho)) - 4(1-\rho)]}$$

We are now able to summarize the effect that post-investigation leniency has on the duration of price wars:

Proposition 1 *In markets where a) the low demand state occurs with high enough probability ($q \geq \tilde{q}$), and b) even if no firm reports, cartel-investigation evidence alone leads to high probability of conviction ($\rho \geq \hat{\rho} \equiv \frac{\mu + \gamma^I + 2(1-2\gamma)}{\mu(2-a) + a\gamma^I + 2(1-2\gamma)}$), offering post-investigation leniency has an adverse side-effect: it allows firms to maintain cartel stability by using shorter price-war periods in their strategy.*

Proof

Consider that both collusive strategies, C and R, are sustainable, i.e. $q \leq \min\{\hat{q}, \bar{q}\}$ and that the leniency provided is sufficient to induce firms to report under investigation. Provided that both firms wish to adopt the shortest punishment period that induces discipline, post-investigation LP shortens (prolongs) price wars when $T_3 < (>)T_1$. Since $T_3 < T_1$ holds for $q > \tilde{q}$, when the latter holds each firm prefers to collude and reveal when the industry is investigated. In this case, the necessary punishment period is shorter than what it would have been in the absence of post-investigation leniency. On the other hand, if $\rho < \hat{\rho}$, $\tilde{q}$ is larger than $\hat{q}$ and $T_3 < T_1$ never holds. ■

When $\rho < \hat{\rho}$ $\tilde{q}$ is higher than $\bar{q}$, thus, for any $q < \bar{q}$ firms would prefer not to report the cartel even if the AA had already launched an inspection. If ρ is greater than $\hat{\rho}$, strategy R is both incentive compatible and more profitable for $q \in [\tilde{q}, \bar{q}]$.⁸

The above analysis shows that the impact of fine reductions on the length of competitive price wars varies as both, low demand and conviction become more or less likely. When the probability of conviction is low, the introduction of post-investigation LP always prolongs the competitive phase that is necessary for cartel stability. On the other hand, when the investigation alone can provide sufficient evidence as to render conviction highly probable without the help of any firm's post-investigation reporting, the added value of the latter is low and potentially outweighed by the cost of leniency in terms of shorter price wars. Such an outcome is possible if negative demand shocks are expected to occur frequently in the future. Moreover, the difference $T_1 - T_3$ increases with q , since the loss of cartel dissolution due to post-

⁸ When $\rho \leq \hat{\rho}$ R is less profitable than C since $T_5 \geq T_3 \geq T_1$. Hence, if firms were able to choose the most profitable collusion, post-investigation leniency would have no impact on collusion for low values of ρ , since firms would choose not to report and to compete for T_1 periods even if an investigation had opened. For $\rho > \hat{\rho}$, R is more profitable than C when $q > \tilde{q}$. Both firms report after investigation and compete for T_3 periods when a demand shock occurs.

investigation reporting decreases, thus making R even more attractive than C. Note that when ρ is high enough, i.e. when $\rho > \frac{2\delta + (\gamma^I + \mu)(1-\delta)}{2\mu + \delta[2 - \alpha\gamma^I - \mu(2-\alpha)]}$, R is more profitable than C and the effect described in proposition 1 holds for every value of $q \in (0, \bar{q}]$.⁹

The next proposition determines the effect of post-investigation leniency on the maximum level of q that allows collusion to be sustainable:

Proposition 2 *A post-investigation LP with generous fine reductions to the reporting firm may induce cartel formation in situations where the cartel would have been otherwise unstable. More specifically, fine reductions corresponding to $\gamma^I < \tilde{\gamma}^I = \frac{\mu(2\rho - 1 - \alpha\rho) - 2(1-\rho)(1-2\gamma)}{1-\alpha\rho}$ extend the range of values of q for which the cartel is sustainable.*

Proof

Setting $\hat{q} < \bar{q}$ and solving for γ^I yields $\gamma^I < \tilde{\gamma}^I$. Hence, an overwhelming post-investigation leniency allows firms to sustain collusion for $q \in (\hat{q}, \bar{q}]$. Note that no collusion was sustainable for $q > \hat{q}$ when leniency was restricted only to firms reporting before an inquiry. ■

Offering excessive post-investigation leniency extends collusion sustainability to values of q for which the cartel would not have been sustainable had leniency been limited to only pre-investigation reporting. An increase in the probability of conviction without reporting reduces the value of the low-demand probability threshold below which strategy C is sustainable. On the other hand, as the fine-reduction due to post-investigation leniency becomes more generous, strategy R becomes more likely to be stable. Hence, for a given probability of conviction, a more lenient treatment of the reporting parties results in a more stable collusive agreement.¹⁰

⁹ In other words, given that conviction of an investigated cartel becomes probable enough, $\tilde{q}$ becomes negative and R is both sustainable with shorter punishment periods and more profitable than C for every positive value of q below $\bar{q}$.

¹⁰ Note that $\bar{q}$ increases while $\hat{q}$ decreases with ρ .

A numerical example

Consider that $\delta = 0.85$, $\mu = 2.5$, $a = 0.15$ and $\gamma = 0$. Provided that post-investigation reporting is awarded with lenient treatment ($\gamma^I = 0.2$)¹¹ and that $\rho = \frac{2}{3}$, V^m and V^r are sustainable when q is lower than $\hat{q} = 0.253$ and $\bar{q} = 0.232$ respectively. Since $T_3 \geq T_1$ holds for $q \geq \tilde{q} = 0.327$, setting $\gamma^I = 0.2$ has clearly a positive impact on cartel deterrence, prolonging the competitive phase of the milder collusive strategy. On the other hand, if $\rho = 0.75$, the critical values of q are $\bar{q} = 0.245 > \hat{q} = 0.22 > \tilde{q} = 0.086$. Under this assumption, firms choose to collude and reveal under investigation for $0.086 \leq q \leq 0.245$ competing for $T_3 (< T_1)$ periods when they observe zero profits. For $0 \leq q < 0.086$, firms are forced to opt for the less profitable collusive strategy and to compete for longer than T_1 period. When $\rho < 0.68$, $\tilde{\gamma}^I$ is negative and excessive fine reductions described in proposition 2 are not applicable. On the contrary, if $\rho = 0.75$ the critical value of γ^I is $\tilde{\gamma}^I = 0.53$ and the effect described in proposition 2 may apply.

Note finally that the results of this paper have been developed under the assumption that q is common knowledge, which results to that all critical values T_h , $h = 1, 2, 3, 4$, being common to both firms' strategies. This assumption simplifies the exposition but is by no means crucial for the results.¹² Since the collusive outcome requires communication between the two firms, the latter must agree upon a common duration of the punishment period. If their perception of q differs, the punishment must be at least as long as to induce compliance of the firm with the highest estimate of q . Since T_1 (and T_3 in the case of post-investigation LP) is increasing in q , that punishment period will also induce compliance of the firm with the lower estimate of q .¹³

¹¹ Under these parameter values, R is incentive compatible for any non-negative T . The critical value of ρ is 0.706.

¹² We are grateful to an anonymous referee for raising this issue.

¹³ The upper bound to the number of punishment periods imposed by the presence of LP (T_2 for C, and T_4 for R) is decreasing in q and satisfied as long as q is lower than $\hat{q}$ and $\tilde{q}$ for C and R respectively.

4 Concluding remarks

This paper investigates the effect of LPs on firms' incentives to collude when the actions of a firm are not perfectly observable by its rival, and demand is stochastic. Assuming that the AA discovers cartels with a given probability and the fine imposed in case of conviction represents a fraction of the cartel-induced profits, we show that increases in the probability of a negative demand shock affect positively the effectiveness of the LP. In markets with low probability of negative demand shocks, the LP must offer substantially higher fine reductions in order to destabilize the cartel. Under the fairly common assumption of detection and conviction rate of around 0.15 and 0.8 respectively, offering full leniency is not sufficient to destabilize the cartel if the probability of a negative demand shock is less than 0.235. On the other hand, when the LP is not effective in destroying the cartel, it will not affect either the length of the price war period.

Often the AA provides lenient treatment for reporting parties even after the opening of the inspection. In markets where the low demand state is expected to occur with high frequency and investigation alone is able to provide sufficient evidence as to make the conviction of an existing cartel highly probable, post-investigation leniency may exhibit undesirable side-effects. First, it may induce cartel-formation in circumstances where, in its absence, any attempt to coordinate pricing would have failed as being unsustainable. Second, it may shorten the punishment period during the pre-investigation life of an existing cartel. This implies longer periods of high prices and low welfare. Both side-effects are likely in cases where investigation alone can bring about powerful evidence, leading to high conviction-probability without need for self-reporting. They constitute, therefore, a strong point against post-investigation leniency with small added value. On the other hand, when investigation is not able to produce sufficient evidence for conviction, on top of being necessary for conviction, post-investigation leniency may also have an additional positive impact on welfare through increasing the duration of price wars.

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