Inspecting Cartels over Time: with and without Leniency Program*

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Abstract

Research on cartel inspection has focused on the dynamic behaviors of firms but not so much on the dynamic behavior of the regulator. This paper allows the antitrust authority to choose the level of cartel monitoring intensity and its varying patterns. Specifically, we compare stationary monitoring policies with "switching" policies that randomize cartel-detecting probabilities over time with the same mean probability as the former. Under a simplified Bertrand competition, (i) without leniency, both policies have the same effect on cartel deterrence, and (ii) with leniency, switching policies can use lower amnesty rates (reduction of the fine) without compromising the effectiveness of cartel deterrence. The synergy between randomizing monitoring intensity and leniency arises because a deviating firm can use leniency to increase the deviation value only in high-intensity periods, which makes collusion more difficult.

Key words: dynamic regulation, collusion, leniency program, repeated game.

JEL classification: C73, L13, L41

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1 Introduction

Research on cartel inspection has focused on the dynamic behaviors of firms but not so much on the dynamic behavior of the regulator (e.g., see surveys by Ivaldi et al. (2003), Marshall and Marx (2012), and Marvão and Spagnolo (2013)). It is often assumed that the detection probability and the antitrust policy are stationary.[1] In this paper, we allow the antitrust authority (AA hereafter) to choose not only the monitoring intensity but also whether to keep the intensity stationary or to vary it over time.[2] The monitoring intensity determines the detection probability of firms' collusion[3], and if collusion is detected, both firms must pay a fine. When the AA varies the monitoring intensities, firms can also choose whether to collude depending on the realized monitoring intensity of that period.

In the repeated game framework, it is often claimed (e.g., Rotemberg and Saloner (1986) and Dal Bó (2007)) that fluctuations in the environment make collusion more difficult. Thus, one may expect that, by creating a fluctuation of the probability of cartel detection (or market-monitoring intensities), the AA can deter collusion more effectively. The intuition is that firms give up colluding in high monitoring-intensity periods, which reduces the continuation value and incentives to collude even in low-intensity periods.

It turns out that in a simple Bertrand competition model, based on Chen and Rey (2013), this intuition may not be correct. Specifically, by comparing a stationary monitoring policy with nonstationary "switching" policies that have the same mean probability as the stationary policy, we show that both policies have identical effects on cartel deterrence. The reason is that, even though firms learn whether the current period has a high probability of cartel detection, the continuation value of future collusion is based on the *expected* detection probability, which is a fixed mean value. Also, a slight undercutting of the collusive price would not change the expected fines in our setting. These observations imply that the net deviation gain for each

[1]Exceptions include Frezal (2006) and Gärtner (2022). Frezal (2006) advocates rotation policies to investigate industries over time but does not consider leniency programs. Gärtner (2022) analyzes how firms utilize leniency in a dynamic setting where detection probability stochastically evolves over time.

[2]Another interpretation of our model is that the AA continuously varies the monitoring intensities, but it can choose whether to commit to keeping the actual intensity secret (so that firms only know the mean probability) or to announce the intensity to the firms before each period.

[3]As Harrington (2008) points out, there are multiple ways that collusion is detected. In this paper, we focus on tacit collusion, and thus detection means that some firm's collusive action H is discovered. Even if the authority inspects, whether they can discover the collusion is not certain, which is reflected in the model.

firm takes the same value across different-probability states, i.e., the fluctuation of detecting probabilities does not affect the deviation incentives. Still, varying the AA's monitoring intensity may be helpful for at least two cases. First, if the cost of the AA's activity is an inverted-S shape function of the monitoring intensity, making a very low probability state may reduce the expected cost of monitoring. Second, if the firms are global entities and the inspection requires international coordination, it may be challenging for the countries involved to coordinate on a stationary inspection policy.

In the same model with a leniency program installed, the effect of the two kinds of policies can differ. The leniency program is a system to incentivize members of a cartel to report to the AA to reduce the fine and therefore to terminate collusion.[4] The key insight is that the payoff from reporting to the AA is constant regardless of the monitoring policy, and a deviating firm can choose when to denounce the cartel to benefit from leniency. Under switching policies, a deviating firm is willing to use the leniency program only in periods of a high detection probability to improve the deviation payoff. Consequently, switching policies become more effective than a stationary policy. Our findings suggest that leniency programs and fluctuations of the intensities in cartel investigations complement each other. To our knowledge, literature has yet to address this type of synergy.

We organize the paper as follows. Section 2 analyzes the base model without leniency and shows the equal effectiveness result. Section 3 compares stationary policies with the mean-preserving switching policies under leniency programs. Section 4 concludes.

2 Base Model without Leniency

Our base model is a simplified version of that proposed by Chen and Rey (2013). We consider a duopoly market in which firms 1 and 2 play an infinitely repeated game of a simplified Bertrand competition over the discrete time horizon $t = 1, 2, \ldots$. They have the common discount factor $\delta \in (0, 1)$. The one-shot profit of each firm is 0 if both firms compete, B (> 0) if they collude,

[4]For a survey of the leniency programs, see Marvão and Spagnolo (2013). Since we have only two firms, we focus on the most straightforward leniency program in which only the first informant gets amnesty. Landeo and Spier (2020) investigate the optimal design of a leniency program of multiple firms, which chooses the number of firms to get the amnesty and the amnesty rate.

and $2B$ for a firm that deviates from the collusion, in which case the other firm gets 0. Such a situation can be formulated by a **reduced Bertrand game** whose payoff matrix is described by Table 1. Note that actions H and L correspond to collusive and defective behaviors, respectively. We regard (H, H) as a successful cartel and (L, L) as competition. The asymmetric case (H, L) corresponds to the situation where firms once entered into a cartel agreement, but firm 2 alone deviates to a **slightly lower** price. The other asymmetric case (L, H) means that firm 1 alone deviates from the cartel.[5]

	H	L
H	B, B	0, $2B$
L	$2B$, 0	0, 0

Table 1: Reduced Bertrand Game

As in Chen and Rey (2013), collusion (i.e., any action combination other than (L, L)) leaves some evidence that might be found by the AA. A monitoring policy of the AA in a period is represented by a probability p with which the cartel is detected if firms collude.[6] The evidence of collusion lasts only for one period. Hence, even if a cartel is detected, each firm must pay a fine F (constant across periods) only for that period and can restart collusion in the next period. Unlike Chen and Rey (2013), we assume that the detection probability sequence $\{p_t\}$ may depend on the investigation strategy chosen by the AA.[7]

In this paper, we compare the following two types of investigation policies. A *stationary policy* implements the same detection probability over time, i.e., $p_t = p \ \in (0, 1)$ for all t. In contrast, a (mean-preserving) *switching policy* randomizes over two detection probabilities, $p+\alpha$ with probability x and $p - \beta$ with probability $1 - x$ such that $\alpha, \beta > 0$ and $p = x(p + \alpha) + (1 -$

[5]In this reduced Bertrand game, (L, H) and (H, L) are also one-shot Nash equilibria. However, our intention is that the situations in which one firm slightly undercuts the other are not the focus of "collusion" because these are not a Nash equilibrium of the ordinary Bertrand game. In the name of "L", we have two meanings in the reduced game.

[6]To be more precise, p is the probability such that the AA investigates this market *and* succeeds in uncovering cartels. Chen and Rey (2013) distinguish these two events and denote the probability of investigating the market by α and the (conditional) probability of uncovering the cartel by p. Therefore, our p is equivalent to their αp.

[7]In a related research, Gärtner (2022) analyzes a model where detection probability stochastically evolves over time. However, this fluctuation process is exogenously given, hence the AA cannot choose its policy.

$x)(p-\beta)$. That is, in this class, we assume the following equality.

$$\alpha x - \beta(1-x) = 0 \tag{1}$$

Later, we sometimes focus on the symmetric case in which $x = 1 - x = \frac{1}{2}$ and $\alpha = \beta$ $(=: \Delta p)$. Note that $\beta \in (0, p]$ must always hold since $p - \beta$ must be non-negative.

2.1 Incentive condition under a stationary policy

We first focus on the stationary policy where $p_t = p \in (0,1)$ for all $t = 1, 2, \ldots$. If firms successfully engage in a cartel (i.e., play (H, H)) for every period, which we call *full collusion*, the expected profit for each firm, denoted by V, becomes

$$V := B - pF + \delta(B - pF) + \delta^2(B - pF) + \cdots = \frac{B - pF}{1 - \delta}.$$

This (full) collusion is sustainable in a subgame perfect equilibrium if and only if the following trigger strategy combination is a subgame perfect equilibrium (Abreu (1988)): firms play (H, H) as long as no firm deviates from it and will play (L, L) forever[8] once some firm deviates. The trigger strategy combination is a subgame perfect equilibrium if any one-step deviation is not beneficial. Recall that a deviation to L when the other firm is playing H is not considered a competitive behavior, because it is just a slight undercutting of the high price. In other words, the probability of cartel-detection is constant and independent of the action profile of (H, H) or (L, H).[9] Hence, a firm may need to pay the fine even if it deviates from the (tacit) cartel agreement, which makes the deviation payoff $2B - pF$.

Thus, the full collusion is sustainable if and only if the following incentive condition is satisfied.

$$V = \frac{B - pF}{1 - \delta} \geqq 2B - pF \iff \delta \geqq \frac{B}{2B - pF}. \tag{2}$$

When either p or F is 0, (2) reduces to $\delta \geqq \frac{1}{2}$. Throughout the paper, we assume that the

[8]Since (L, L) is a Nash equilibrium of our reduced Bertrand game, playing (L, L) in every period (irrespective of the history) is a subgame perfect equilibrium. This equilibrium would generate 0 profit, which clearly serves as the severest punishment for both firms.

[9]In Section 3.3, we consider an extended model in which cartel-detecting probabilities differ across two types of collusion.

following condition holds so that the firms have a strict incentive to sustain collusion if there is no antitrust enforcement.

$$\delta > \frac{1}{2}. \tag{3}$$

Given (3), the condition (2) can be rewritten as follows.

$$B \geqq \underline{B} := \frac{\delta p F}{2\delta - 1} \tag{4}$$

The condition (4) means that only markets that generate sufficient collusive payoff B can sustain the full collusion and that the class of such markets becomes smaller when the policy-dependent threshold $\underline{B}$ increases. Therefore, $\underline{B}$ can be interpreted as the effectiveness of the antitrust policy.

2.2 Full collusion under switching policies

When the AA chooses a (mean-preserving) switching policy, one of the two different detection probabilities $p+\alpha$ and $p-\beta$ realizes each period with probability x and $1-x$ respectively, such that its average probability is equal to p, i.e., the condition (1) holds.

We call that a period is in the *risky state* if the higher detection probability $p+\alpha$ realizes, while the period is in the *safe state* if the lower detection probability $p-\beta$ realizes. If firms cannot know the realized state before choosing their actions, the game is essentially the same as the one under the stationary policy with p. Thus, we assume that the AA tells firms the detecting intensity before the firms choose the stage-game actions.

There are at least two reasons that the AA may want to use a switching policy. One is the implementation cost of the policies. If the cost of monitoring is a function of p and follows the standard inverted-S shape, it is possible that mixing two different probabilities is cheaper than monitoring with the mean probability for sure. The other is the case that the AA is facing multiple markets to monitor. Then the AA may want to rotate the monitoring activities across markets instead of monitoring all markets every period. The latter benefit is advocated by Frezal (2006).

Under a switching policy, firms can try to collude either in both states (full collusion) or only during safe states in which the lower detection probability is realized (partial collusion).

Consider full collusion. Let V_r (resp. V_s) be the total expected payoff of a firm starting in the risky (resp. safe) state. To sustain (H, H) in both states, the following incentive conditions for the two states must be simultaneously satisfied.

$$V_r := B - (p + \alpha)F + \delta\{xV_r + (1 - x)V_s\} \geqq 2B - (p + \alpha)F \tag{5}$$

$$V_s := B - (p - \beta)F + \delta\{xV_r + (1 - x)V_s\} \geqq 2B - (p - \beta)F \tag{6}$$

Proposition 1 *Assume there is no leniency program. Then, full collusion is sustained in a subgame perfect equilibrium under some stationary policy if and only if full collusion is sustained in a subgame perfect equilibrium under* ***any*** *of its mean-preserving, switching policies.*

Proof. We prove the following: for any $p \in (0, 1)$, any $x \in (0, 1)$, any $\alpha \in (0, 1 - p)$, and any $\beta \in (0, p]$ such that (1) holds, the conditions (5) and (6) are both equivalent to (4).

By the definitions of V_r and V_s, we have

$$\begin{aligned} & xV_r + (1 - x)V_s = B - pF + \delta\{xV_r + (1 - x)V_s\} \\ \iff & xV_r + (1 - x)V_s = \frac{B - pF}{1 - \delta}. \end{aligned}$$

Hence (5) becomes

$$\begin{aligned} & V_r = B - (p + \alpha)F + \delta\frac{B - pF}{1 - \delta} \geqq 2B - (p + \alpha)F \\ \iff & B - \delta\frac{B - pF}{1 - \delta} \geqq 2B \iff B \geqq \frac{\delta pF}{2\delta - 1} \; (= \underline{B}). \end{aligned}$$

(6) also becomes

$$\begin{aligned} & V_s = B - (p - \beta)F + \delta\frac{B - pF}{1 - \delta} \geqq 2B - (p - \beta)F \\ \iff & B - \delta\frac{B - pF}{1 - \delta} \geqq 2B \iff B \geqq \frac{\delta pF}{2\delta - 1}(= \underline{B}). \end{aligned}$$

■

Proposition 1 illustrates that, in the absence of a leniency program, a stationary policy and

any mean-preserving switching policy are identically effective for cartel deterrence. In other words, only the average investigation probability matters to deter full collusion. This is because, in either state, the probability of paying the fine ($p + \alpha$ or $p - \beta$) is the same for collusion and for deviation (and thus cancels out in conditions (5) and (6)), and the continuation payoff of collusion $\delta\{xV_r + (1-x)V_s\}$ depends only on the mean detection probability p.

Under a switching policy, firms may engage in partial collusion such that they choose (H, H) in safe states but (L, L) in risky states. In Appendix A.1, we show that, for each stationary policy, there is a class of mean-preserving switching policies under which the AA can focus only on deterring full collusion: either partial collusion is impossible, or if full collusion is prevented, then partial collusion is also prevented. Therefore, from now on, we only consider full collusion under switching policies to compare with (full) collusion under stationary policies.

3 Policy comparison under a leniency program

Consider a leniency program that allows the first (and only first) informant to benefit from a reduced fine $(1-q)F$ where $q > 0$ is the amnesty rate. Following Chen and Rey (2013), We assume that, in each period, firms simultaneously choose a stage game action from $\{H, L\}$ as well as whether to report the evidence of collusion to the AA.[10]

3.1 Stationary policy with leniency

To sustain full collusion under a stationary detection probability $p_t = p$ for all $t = 1, 2, \ldots$, we focus on the trigger strategy such that both firms choose H and do not report to the AA as long as no firm deviates, but firms choose L forever after if a firm deviates from this path. Note that a deviating firm can choose between not reporting to the AA and using the leniency program, whichever gives a lower (expected) fine. Hence, the following incentive condition must be satisfied to sustain full collusion.

$$V = \frac{B - pF}{1 - \delta} \geqq 2B - \min\{pF, (1-q)F\} \tag{7}$$

[10] If (L, L) is chosen and a firm chooses to report the evidence of collusion, then nothing is reported since there is no evidence of collusion.

Leniency programs are relevant only if it is used in the optimal deviation, i.e.,

$$p > (1-q) \iff q > 1-p. \tag{8}$$

In what follows, we assume (8). Let Δq (> 0) be the gap between q and $1-p$. That is,

$$\Delta q := q - (1-p) = q + p - 1 \ (> 0).$$

This Δq can be interpreted as the attractiveness of using the leniency program as compared to taking risks to be detected. The condition (7) can be rewritten as follows.

$$\begin{aligned} V = \frac{B - pF}{1-\delta} &\geqq 2B - (1-q)F \\ \iff B &\geqq \frac{\{p - (1-\delta)(1-q)\}F}{2\delta - 1} =: B^*(\Delta q). \end{aligned} \tag{9}$$

By computation,

$$B^*(\Delta q) = \frac{\{p - (1-\delta)(p - \Delta q)\}F}{2\delta - 1} = \underline{B} + \frac{(1-\delta)F}{2\delta - 1} \cdot \Delta q.$$

This implies that $B^*(\Delta q) > \underline{B}$ (as long as $\Delta q > 0 \iff q > 1-p$). As is pointed out by Chen and Rey (2013), it is always desirable to offer some leniency, since that would tighten the incentive condition and make collusion harder to sustain.

3.2 Switching policy with leniency

For simplicity, let us consider the switching policy with $x = \frac{1}{2}$ and $\alpha = \beta = \Delta p$.[11] To sustain full collusion, the following two incentive conditions must be satisfied.

$$V_r := B - (p + \Delta p)F + \delta\left(\frac{V_r + V_s}{2}\right) \geqq 2B - \min\{(p+\Delta p)F, (1-q)F\} \tag{10}$$

$$V_s := B - (p - \Delta p)F + \delta\left(\frac{V_r + V_s}{2}\right) \geqq 2B - \min\{(p-\Delta p)F, (1-q)F\} \tag{11}$$

[11]We can do a similar analysis with general mean-preserving switching policies. Specifically, Lamma 1 always holds. However, the incentive conditions become complex formulas of α, β, and x, and the policy implications of changing the amnesty rate etc. become unclear because we have two free parameters out of α, β, and x.

Lemma 1 *If collusion in risky states is sustained, it is sustained in safe states, that is,* (10) *implies* (11).

Proof. Subtracting $2\Delta pF$ from both sides of the inequality of (11), we have

$$B - (p + \Delta p)F + \delta \left(\frac{V_r + V_s}{2} \right) \geqq 2B - \min\{(p + \Delta p)F, (1 - q)F + 2\Delta pF\}, \tag{12}$$

which is equivalent to (11). Note that $\Delta p \geqq 0$ implies that

$$\begin{aligned} &\min\{(p + \Delta p)F, (1 - q)F + 2\Delta pF\} \geqq \min\{(p + \Delta p)F, (1 - q)F\} \\ \iff\ &2B - \min\{(p + \Delta p)F, (1 - q)F\} \geqq 2B - \min\{(p + \Delta p)F, (1 - q)F + 2\Delta pF\}. \end{aligned}$$

Therefore, the condition (10) implies (12). ■

In light of Lemma 1, if the AA wants to deter full collusion, it must prevent collusion in risky states, i.e., (10) must not hold. Note also that our assumption (8) implies that $p + \Delta p > (1 - q)$, hence the optimal one-step deviation payoff (the RHS) of (10) is $2B - (1 - q)F$.

By the definition of V_r and V_s in (10) and (11), we have

$$\begin{aligned} &\frac{V_r + V_s}{2} = \frac{1}{2}\{B - (p + \Delta p)F\} + \frac{1}{2}\{B - (p - \Delta p)F\} + \delta \left(\frac{V_r + V_s}{2} \right) \\ \iff &\frac{V_r + V_s}{2} = B - pF + \delta \left(\frac{V_r + V_s}{2} \right) \\ \iff &\frac{V_r + V_s}{2} = \frac{B - pF}{1 - \delta} \Rightarrow V_r = \frac{B - pF}{1 - \delta} - \Delta pF. \end{aligned}$$

Since $1 - q = p - \Delta q$, the optimal one-step deviation payoff is

$$\begin{aligned} 2B - (1 - q)F =& 2B - (p - \Delta q)F \\ =& 2B - pF - \Delta pF + (\Delta p + \Delta q)F. \end{aligned}$$

Therefore, the relevant incentive condition under the switching policy with leniency becomes as follows.

$$V_r = \frac{B - pF}{1-\delta} - \Delta pF \geqq 2B - pF - \Delta pF + (\Delta p + \Delta q)F$$

$$\iff B \geqq \frac{\{p - (1-\delta)(p - \Delta p - \Delta q)\}F}{2\delta - 1} =: B^{**}(\Delta p, \Delta q). \tag{13}$$

By computation,

$$B^{**}(\Delta p, \Delta q) = \underline{B} + \frac{(1-\delta)F}{2\delta - 1} \cdot (\Delta p + \Delta q) = B^*(\Delta q) + \frac{(1-\delta)F}{2\delta - 1} \cdot \Delta p.$$

When $\Delta q > 0$, we obtain

$$B^{**}(\Delta p, \Delta q) > B^*(\Delta q)(> \underline{B}). \tag{14}$$

Hence, with the leniency program installed, the class of markets in which full collusion is sustainable becomes smaller under symmetric switching policies than under a stationary policy using the mean probability.

The intuition of the results so far is illustrated in Figure 1. First, with a relevant leniency program ($\Delta q > 0$), the deviation value increases. This raises the minimum B to sustain collusion under a stationary policy to $B^*(\Delta q)$. Second, under switching policies, we need that the collusive value V_r in risky state is not less than the deviation value. Since V_r is lower than the value V under the stationary policy, this raises the minimum B to even a higher value $B^{**}(\Delta p, \Delta q)$.

We can also see the effects of changes in the probability spread Δp, the amnesty rate q, and the attractiveness of the leniency program Δq. The formula (13) shows that the bound $B^{**}(\Delta p, \Delta q)$ is increasing in Δp and depends only on the sum $\Delta p + \Delta q$. Starting from a stationary policy with the bound $B^*(\Delta q)$, if the AA wants to reduce the amnesty rate q (i.e., shift down the green line of the deviation value $2B - (1-q)F$), then the AA can introduce a symmetric mean-preserving switching policy with sufficiently high Δp (i.e., lowers the relevant collusion payoff from V to V_r) to cancel out the negative effect on the anti-trust policy. These findings are summarized as follows.

Proposition 2 *1. Under a given p and a leniency program with $q > 1 - p$, any symmetric*

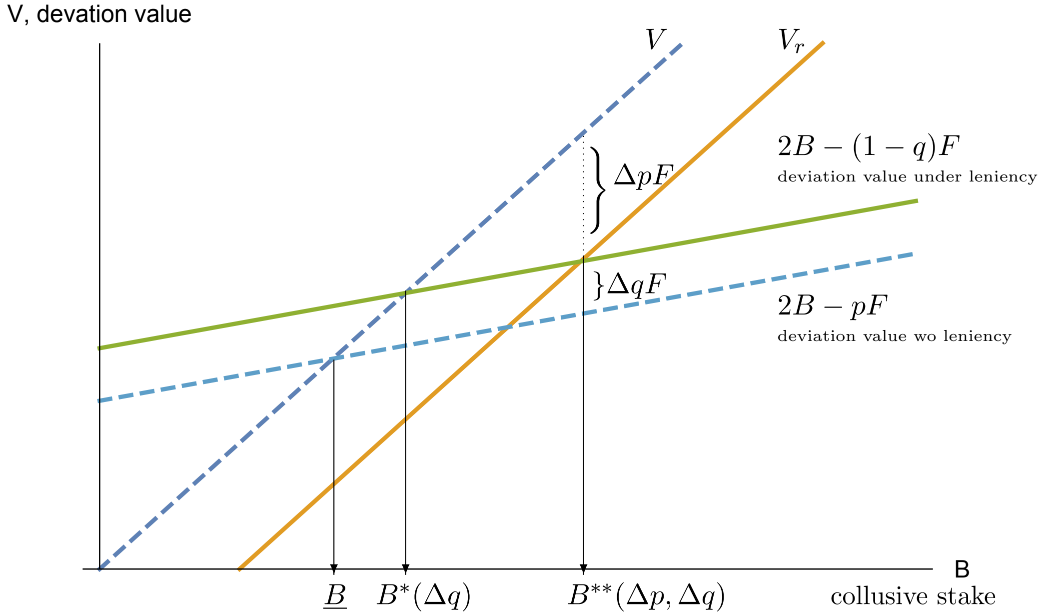

Figure 1: Comparison of the value functions under two policies

mean-preserving switching policy makes full collusion more difficult than the stationary policy with detection probability p. Moreover, sustaining full collusion becomes more difficult as the spread Δp of the detection probabilities is increased.

2. *Whenever a stationary policy with some amnesty deters a cartel, there always exists its mean-preserving switching policy that can also deter the same cartel with* ***strictly smaller*** *amnesty rates.*

Therefore, by implementing nonstationary policies, the AA can reduce the amnesty rate without compromising the effectiveness of cartel deterrence. In this way, leniency programs and nonstationary cartel investigations complement each other.

3.3 Generalizing cartel-detecting probabilities

Note that the qualitative result is robust to some changes in the model, in particular, even if the probability of getting fined at (L, H) is different from the one at (H, H), which can be more natural. One might think that the fine levels at (H, H) and (L, H) can also differ since the latter gives significantly larger profits to the (deviating) firm. We found that it is optimal for the AA not to change the fine levels depending on the action profiles. (See Appendix A.2.)

We continue to denote p being the probability of detection at (H, H) under a stationary policy. Therefore, the total expected payoff V from full collusion is unchanged:

$$V = \frac{B - pF}{1 - \delta}.$$

Take a constant γ such that $-\{1 - (p + \alpha)\} < \gamma < p - \beta$ and let $p - \gamma$ be the probability of detection at (L, H)[12], that is, the firm that slightly undercuts the collusive price is charged a fine with probability $p - \gamma$ under the stationary policy. Then the incentive condition of (2) becomes

$$V = \frac{B - pF}{1 - \delta} \geqq 2B - (p - \gamma)F. \tag{15}$$

Suppose that a switching policy also differs in the probability of detection by the same γ at (L, H), given a state. That is, in the risky state, the probability of detection at (H, H) is $p + \alpha$, while the one at (L, H) is $p + \alpha - \gamma$. In the safe state, the detection probability at (H, H) is $p - \beta$, but the one at (L, H) is $p - \beta - \gamma$.

Without leniency, the incentive conditions (5) and (6) for full collusion become as follows.

$$V_r = B - (p + \alpha)F + \delta\{xV_r + (1 - x)V_s\} \geqq 2B - (p + \alpha - \gamma)F \tag{16}$$

$$V_s = B - (p - \beta)F + \delta\{xV_r + (1 - x)V_s\} \geqq 2B - (p - \beta - \gamma)F \tag{17}$$

As in our analysis in Section 2.2, (15) is equivalent to the conditions (16) and (17). Therefore, the two types of policies are identically effective in the absence of a leniency program.

With leniency, the incentive condition (7) under the stationary policy becomes

$$V = \frac{B - pF}{1 - \delta} \geqq 2B - \min\{(p - \gamma)F, (1 - q)F\}. \tag{18}$$

The RHS of (18) implies that a leniency program is relevant only at higher rates of q than before, i.e., when $p - \gamma > 1 - q$. Under a switching policy with $x = \frac{1}{2}$ and $\alpha = \beta = \Delta p$, the

[12]To guarantee that the probabilities of detection under a switching policy are well-defined, $p - \beta - \gamma > 0$ and $p + \alpha - \gamma < 1$ must hold. Otherwise, we can let $\gamma < 0$.

incentive conditions for full collusion are as follows.

$$V_r = B - (p + \Delta p)F + \delta \left(\frac{V_r + V_s}{2} \right) \geqq 2B - \min\{(p + \Delta p - \gamma)F, (1 - q)F\}$$
$$V_s = B - (p - \Delta p)F + \delta \left(\frac{V_r + V_s}{2} \right) \geqq 2B - \min\{(p - \Delta p - \gamma)F, (1 - q)F\}$$

By the same logic as the one in Section 3.2, the symmetric mean-preserving switching policies are more effective than the stationary policy, under the leniency programs satisfying $p - \gamma > 1 - q$.

4 Conclusion

In this paper, we study how cartel behaviors are affected by dynamic antitrust enforcement by the regulator. Our focus is to compare a stationary investigation policy with its mean-preserving switching policies that randomize cartel-detecting probabilities for each period. We illustrate that, in the simple Bertrand-type competition model and without a leniency program, the two types of policies are identically effective. Whereas, in the presence of leniency programs, the switching policies can outperform the stationary policy in deterring collusion and reducing the amnesty rate. These findings suggest that leniency programs and fluctuations in cartel investigation complement each other. We expect this would provide a new scope for competition policy.

To derive the above results in the simplest possible setting, the current model assumes that there are only two firms, they have only two actions, and the AA uses only two different investigating probabilities under switching policies. Allowing continuous prices instead of binary actions would be straightforward. We also expect that considering more than two firms or more than two levels of monitoring intensities does not give qualitatively new insight as long as only the first informant gets the amnesty. However, a model with more than two firms involves more policy choice variables: how many firms can get the amnesty and how the amnesty rates should differ in the order of report. Landeo and Spier (2020) have already investigated this type of design problem of the optimal ordered leniency program. It would be an important future research topic to analyze how non-stationary detection probabilities affect the optimal ordered-leniency policy.

Another simplifying assumption is that the difference of cartel-detecting probabilities between (H, H) and (L, H) is constant, i.e., it was either 0 (Section 2.2) or a fixed value γ (Section 3.3). While generalizing the structure of the cartel detection process is important, we leave it for future research.[13]

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A Appendix

A.1 Partial collusion under switching policies

Consider partial collusion in which the two firms choose (H, H) in safe states and (L, L) in risky states. To achieve such partial collusion under a switching policy, only the incentive condition at the safe state needs to be satisfied. Let V_{pr} (resp. V_{ps}) be the total expected profit of a firm starting in a risky (resp. safe) state under the partial collusion strategy. These values must satisfy the following simultaneous equations.

$$V_{pr} = 0 + \delta\{x \cdot V_{pr} + (1-x)V_{ps}\}$$
$$V_{ps} = B - (p-\beta)F + \delta\{x \cdot V_{pr} + (1-x)V_{ps}\}$$

Multiplying x and $(1-x)$ to both sides of the two equalities and adding the two equalities, we have

$$\{x \cdot V_{pr} + (1-x)V_{ps}\} = (1-x)\{B - (p-\beta)F\} + \delta\{x \cdot V_{pr} + (1-x)V_{ps}\}.$$

Hence

$$\{x \cdot V_{pr} + (1-x)V_{ps}\} = \frac{(1-x)}{(1-\delta)}\{B - (p-\beta)F\},$$

so that

$$V_{pr} = \frac{\delta(1-x)}{(1-\delta)}\{B - (p-\beta)F\},$$
$$V_{ps} = \left[1 + \frac{\delta(1-x)}{(1-\delta)}\right]\{B - (p-\beta)F\}.$$

The incentive condition for partial collusion is that firms do not deviate from (H, H) in the safe state, i.e.,

$$V_{ps} \geqq 2B - (p-\beta)F$$
$$\Longleftrightarrow B(2\delta - 1 - \delta x) \geqq \delta(1-x)(p-\beta)F. \tag{19}$$

Remark 1 *1. If the AA sets a switching policy with a high probability of the risky state such* *that* $2\delta - 1 - \delta x \leqq 0$*, then it is impossible for the firms to sustain partial collusion irrespective of other policy parameter values,* p*,* β*, and* F*.*

2. If the AA sets a low probability of the risky state so that $2\delta - 1 - \delta x > 0$ *(* $\iff \frac{2\delta-1}{\delta} > x$*), then partial collusion is more difficult to sustain than full collusion if and only if*

$$\frac{(1-\delta)p}{2\delta-1} \geqq \alpha.$$

Proof. 1 is straightforward from (19).

To prove 2, assume that $2\delta - 1 - \delta x > 0$. Then the incentive condition (19) becomes

$$B \geqq B_{ps} := \frac{\delta(1-x)}{2\delta-1-\delta x}(p-\beta)F.$$

For the proof, it suffices to show $B_{ps} \geqq \underline{B}$. To compare B_{ps} with $\underline{B}$, we have

$$\begin{aligned} \frac{B_{ps}-\underline{B}}{\delta F} = \frac{(1-x)(p-\beta)}{2\delta-1-\delta x} - \frac{p}{2\delta-1} &= \frac{(1-\delta)px-(1-x)\beta(2\delta-1)}{(2\delta-1)(2\delta-1-\delta x)} \\ &= \frac{x\{(1-\delta)p-(2\delta-1)\alpha\}}{(2\delta-1)(2\delta-1-\delta x)}, \end{aligned} \tag{20}$$

where the last equality is derived by (1). Since $x > 0$, $2\delta - 1 > 0$ (from (3)) and $2\delta - 1 - \delta x > 0$,

$$B_{ps} \geqq \underline{B} \iff \frac{(1-\delta)p}{2\delta-1} \geqq \alpha.$$

■

Remark 1 (item 1) shows that, when the AA sets the probability of the risky state x to be large enough or the increased detection probability α to be small enough (given the upper bound to x, this means that the reduction of the detection probability β in the safe state is small), the AA can focus only on deterring full collusion under such switching policies.

A.2 Action-dependent policies

In our benchmark model, we assume that (i) the detection probability p and (ii) the fine F (when the AA succeeds in detecting collusion) are independent of the action profile (H, H), (L, H), or (H, L). In this appendix, we consider an extended model in which these values depend on whether collusion is symmetric (H, H) or asymmetric $(L, H)/(H, L)$. For example, one might advocate that the fine level must depend on the profits earned by the collusive firms. We keep using the same notations, p and F, for the values in the symmetric action case. Let $\tilde{p}$ and $\tilde{F}$ be the corresponding values in the asymmetric case. Then, the incentive condition to sustain collusion under a stationary but action-dependent policy becomes

$$V = \frac{B - pF}{1 - \delta} \geqq 2B - \tilde{p}\tilde{F} \iff B \geqq \frac{pF - (1 - \delta)\tilde{p}\tilde{F}}{2\delta - 1} \tag{21}$$

Let us denote the difference of the two fine levels by ΔF, that is,

$$\tilde{F} = F + \Delta F. \tag{22}$$

Since the amount of the fine is usually non-decreasing in the amount of the (excess) profits of the colluding firms, we assume $\Delta F \geqq 0$. Substituting (22) into (21), the incentive condition is now expressed as

$$B \geqq \frac{pF - (1 - \delta)\tilde{p}(F + \Delta F)}{2\delta - 1} = \underline{B} - \frac{1 - \delta}{2\delta - 1}\{F(\tilde{p} - p) + \delta\tilde{p}\Delta F\} \tag{23}$$

Note the RHS of (23) is decreasing in ΔF. This implies that collusion becomes *easier* as the gap ΔF gets larger. Given that the amount of fine is non-decreasing, it is optimal to set $\Delta F = 0$. That is, for stationary policies, the AA should charge the constant fine $F = \tilde{F}$ independent of whether collusion is symmetric or asymmetric.