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Abstract

We study cartel detection when two public authorities operate separate leniency programs within the same jurisdiction, as in Korea. We develop a simple repeated-game model to compare single-agency enforcement with dual-agency enforcement, to distinguish independent operation from cooperation, and to examine how the structure of leniency relief affects reporting incentives. When the two programs operate independently and do not recognize each other's leniency status, firms may have weaker incentives to self-report, and reporting can become concentrated in only one program. Cooperation that recognizes leniency rank across authorities restores a race to report and can make self-reporting attractive under a broader range of enforcement environments. The analysis also shows that cooperation is most reliable when early applicants receive comparable treatment across authorities: when second-in-line relief is available only in the administrative program, stronger criminal exposure can reduce the effectiveness of cooperation by raising the residual risk borne by non-first applicants. The policy implication is that effective dual-agency leniency can be achieved through a narrow form of coordination that verifies marker status and aligns the relief structure across authorities while preserving confidentiality.

Keywords: Antitrust, Cartel Detection, Collusion, Dual-agency Enforcement, Leniency Program

JEL: K21, K42, L41, L44

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1 Introduction

Cartels are difficult to detect because key communications and evidence are privately held by the participants, and market monitoring alone often does not provide sufficient proof for enforcement. Leniency programs address this information problem by offering reductions in sanctions to cartel members who disclose evidence. When relief is concentrated on early applicants, the program creates a race to report: firms have an incentive to pre-empt rivals and approach the authority before the cartel is detected through ordinary investigation.

Korea provides a setting in which this race-to-report logic can be altered by institutional design. It has long operated an administrative leniency program through the Korea Fair Trade Commission (KFTC). In 2020, the Supreme Prosecutors' Office of Korea (SPO) introduced a separate criminal leniency program for cartel cases. The two programs coexist within the same jurisdiction but need not function as a unified system from the perspective of a reporting firm. If leniency status obtained at one authority is not recognized by the other, a firm that reports may still face substantial residual liability before the non-recognizing authority. This can weaken the incentive to self-report even when the authorities intensify enforcement.

This paper studies cartel detection under dual-agency enforcement when the two authorities run distinct leniency programs and may or may not coordinate. We develop a simple repeated-game model of a triopoly cartel and compare institutional environments that differ along two dimensions. The first dimension is whether the authorities operate independently or cooperate. Cooperation is modeled as both an increase in the effective likelihood that concealment is detected and a recognition of leniency rank across authorities, so that a firm that secures an early position at one authority receives consistent treatment at the other. The second dimension is the structure of relief: we compare regimes that grant relief only to the first applicant with regimes that also grant partial relief to the second, and we allow this second-in-line relief to be symmetric across authorities or available only at the administrative authority, as in current Korean practice.

The analysis focuses on a policy-relevant margin. The intensity of enforcement and the degree of coordination jointly determine the baseline probability that a cartel is detected, which is shaped by investigative resources and institutional arrangements. By contrast, the extent to which firms value future collusive profits is private and heterogeneous. This makes it natural to characterize how institutional design affects the detection environment required for leniency to induce self-reporting and, in turn, how these incentives feed back into cartel sustainability.

The model delivers three qualitative results. First, when the two authorities run separate programs without recognizing each other's leniency status, self-reporting requires a relatively strong background threat of detection, and partial relief offered by only one authority can generate strategic reporting to that authority alone. Second, when the authorities cooperate and recognize leniency rank, the detection environment required for self-reporting is weaker, because cooperation restores the race to report and reduces the attractiveness of concealment. Third, cooperation is most reliable when the relief structure is aligned across authorities. When only one authority offers second-in-line relief, the effectiveness of cooperation becomes sensitive to the relative severity of criminal exposure, and in some environments cooperation can raise detection and still fail to induce reporting. These results imply that institutional design can substitute for enforcement intensity by making self-reporting incentives operative at lower levels of investigative capacity.

The remainder of the paper proceeds as follows. Subsection 1.1 reviews related work on leniency design and enforcement coordination. Section 2 presents the model and institutional environments. Section 3 characterizes equilibria and derives the self-reporting thresholds and collusion-sustainability conditions across regimes. Section 4 discusses implications for cooperation, sanction design, and the choice of the detection rate. Section 5 concludes.

1.1 Literature review

Early studies on leniency programs examine their design and effectiveness as tools for cartel detection and deterrence. Motta and Polo (2003), one of the earliest works on this topic, analyze how leniency influences cartel behavior. By comparing firms' strategies of "Collude & Reveal" and "Collude & Not Reveal," they show that leniency may lower the expected cost of collusion and increase the ex ante incentive to collude, yet the higher ex post probability of detection outweighs this effect and makes leniency an effective policy instrument. Aubert et al. (2006) investigate the role of active rewards (bounties), in contrast to traditional leniency programs that only reduce fines. They find that combining fine reductions with rewards can promote the preservation of evidence and encourage self-reporting, thereby strengthening deterrence. Buccirossi and Spagnolo (2006) emphasize another possibility: while leniency can deter repeated illegal transactions, a moderate program that grants both fine reductions and rewards may instead function as a mechanism that makes one-shot illegal transactions feasible. These studies show that the deterrent effect of leniency and the improvement of cartel enforcement efficiency depend on how the program is designed and implemented.

Subsequent research has focused on the optimal design of leniency programs. Harrington (2008) studies how leniency should be structured in order to minimize the frequency of collusion. He shows that a leniency program increases the incentive of a deviator to self-report (Deviator Amnesty Effect), but at the same time raises the expected benefit of collusion by taking into account the possibility of future reports while the cartel is sustained (Cartel Amnesty Effect). He also points out that leniency generates a competition among cartel members to self-report (Race to the Courthouse Effect), and that when the competition authority already possesses sufficient evidence, it is not always optimal to grant full leniency to a self-reporting firm. Harrington (2013) analyzes how leniency programs operate when firms hold private information about the likelihood of being prosecuted by the competition authority. He shows that firms' decisions to self-report are driven by both the risk of being prosecuted (prosecution effect) and the fear that another firm will report first (pre-emption effect). In an environment with private information, firms may rush to self-report even when the prosecution effect is weak, as they anticipate that rivals may disclose. This implies that when leniency offers sufficient relief, the pre-emption effect induces firms to apply, and as the risk of prosecution increases, this effect becomes stronger.

Chen and Rey (2013) investigate the optimal design of leniency programs by considering operational elements such as the allowance of pre-investigation or post-investigation applications, the restriction to the first-informant, and the treatment of repeat offenders. While leniency reduces the sustainability of collusion, overly generous programs may encourage abuse through strategies such as "collude-and-report." They emphasize that granting immunity only to the first reporter is important to strengthen deterrence and limit abuse. They also stress that pre-investigation reporting should always be allowed and that repeat offenders should be excluded from leniency. Motchenkova and Van Der Laan (2011) examine how leniency works depending on firm size and diversification. They find that large firms are less likely to initiate collusion but, once involved, have weaker incentives to report, whereas leniency has a stronger deterrent effect on smaller firms. They argue that leniency should therefore be operated with this asymmetry in mind. These studies demonstrate that the effectiveness of leniency programs can vary greatly depending on detailed factors such as the scope of immunity, the conditions for reporting, and firm size.

Several other studies examine how additional institutional arrangements of competition authorities influence the functioning of leniency programs. Buccirossi et al. (2020) analyze whether private damages actions undermine the effectiveness of leniency. Since leniency applicants provide cartel evidence to the competition authority, they may become the main target in civil lawsuits. The authors argue that, in order to minimize conflicts between public and private enforcement and to maximize the effectiveness of leniency programs, it is optimal to minimize the civil liability of immunity recipients and to guarantee access to all submitted evidence. Strathearn et al. (2025) investigate the impact of settlement procedures on leniency programs. They show that settlements reduce the cost of collusion and therefore have a pro-collusive effect, but at the same time ensure the breakdown of collusion once investigations are initiated, which creates an anti-collusive effect. Considering these dual effects, they emphasize that when leniency and settlements are jointly implemented, they can become complementary instruments of law enforcement. In addition, OECD (2023) highlight that leniency applications declined by 58 percent across OECD countries between 2015 and 2021. They stress that, although leniency remains a core tool for cartel detection and deterrence, complementary measures are needed for more effective enforcement. These include the refinement of econometric techniques to identify signs of collusion through data analysis (cartel screening), the introduction of whistleblowing systems that provide anonymity and rewards to individuals supplying evidence, and proactive detection through active investigation of industries and markets where collusion is likely. These discussions suggest that the effectiveness of leniency can only be maximized when it is operated in conjunction with, and in consideration of, other enforcement instruments and institutional arrangements.

Recent research analyzes the effects of leniency programs in multiproduct and multimarket collusion. Marx et al. (2015) examine how linking leniency across products affects cartel detection and firm strategies when colluding firms operate in several product markets. They show that multiproduct colluders may adopt a strategy of designating less valuable product markets as a "sacrificial cartel," applying for leniency there in order to reduce the risk of conviction in more important markets. They emphasize that antitrust authorities should take into account such strategic behavior by multiproduct firms. Lefouili and Roux (2012) analyze the impact of the Amnesty Plus program, which grants benefits to a convicted cartel member that provides additional evidence of collusion in other markets. They show that Amnesty Plus entails two opposite effects: a pro-collusive effect, whereby it strengthens the sustainability of collusion across multiple markets, and an anti-collusive effect, whereby it increases the incentive to self-report and thereby shortens the duration of collusion. Choi and Gerlach (2012) study how information sharing among competition authorities in international antitrust cooperation affects firms' incentives to self-report when multinational firms operate in multiple jurisdictions. They find that the sharing of investigative information enhances self-reporting and strengthens deterrence, but that the sharing of all information, including leniency materials, may have the opposite effect of discouraging applications. International Competition Network (2020) stress the importance of ensuring confidentiality and predictability in cross-border enforcement, and argue for cooperation and coordination among competition authorities as well as the establishment of consistent international leniency procedures. These studies indicate that the effectiveness of leniency programs is not determined solely by the design of the program itself, but also depends on market structure and the degree of coordination among enforcement agencies.

Based on this discussion, we analyze Korea's current institutional setting of dual leniency programs, consisting of administrative leniency by KFTC and criminal leniency by SPO. While previous research has primarily modeled a single competition authority within a market or examined the interaction of firms and authorities in multinational contexts, little attention has been given to cases in which two authorities within a single country operate distinct leniency programs. Our analysis focuses on cases where two agencies operate independently or cooperatively, and where their amnesty structures are symmetric or asymmetric, and derives the thresholds of detection probabilities required for leniency to be effective. In this way, we address the question of whether dual-agency leniency programs promote or weaken cartel detection.

2 Model

Firms and Market We consider an infinitely repeated homogeneous-product market with three identical firms. In each period, firms choose whether to adhere to a cartel agreement or to deviate. If all three firms collude, each firm earns collusive profit π_C. If one firm deviates while the other two adhere to the cartel agreement in that period, the deviator earns π_D and the remaining firms earn the collusive continuation payoff for that period. If the cartel collapses and all firms compete, each firm earns the competitive profit π_0. We assume $\pi_D > \pi_C > \pi_0$. Firms discount future payoffs by $\delta \in (0, 1)$ and use grim-trigger strategies: any deviation from the cartel path is followed by permanent reversion to the competitive outcome in all subsequent periods.

Antitrust enforcement There are two public enforcers. The KFTC imposes an administrative monetary sanction F on each cartel participant upon detection, while the imposes a criminal penalty D upon detection. Following Montag and Tremewan (2020), we represent the criminal penalty in monetary-equivalent units and write $\mathsf{D} = \mathsf{KF}$ for some $\mathsf{K} \geqslant 0$.[1] The parameter K then captures the severity of criminal exposure relative to the administrative fine in a transparent way and allows the analysis to characterize how reporting incentives and collusion sustainability vary with the relative weight placed on criminal punishment. In each period, conditional on a cartel being active, each authority detects the cartel with probability $\rho \in (0, 1)$. Unless stated otherwise, we assume both authorities have the same baseline detection probability ρ.

Timing In each period, the following sequence occurs. First, firms simultaneously choose actions in the product market (collude or deviate) and, if a leniency program is available, each firm simultaneously decides whether to apply for leniency to the KFTC, the SPO, or both. Second, enforcement actions occur: conditional on collusion, each authority investigates and detects with probability governed by the institutional environment described below. Third, sanctions and leniency are applied based on detection outcomes and the realized leniency ranking (first applicant, second applicant, or no applicant), and firms receive period payoffs net of expected sanctions. The stage game then repeats. We focus on symmetric equilibria in which firms use identical strategies on the equilibrium path.

Cooperation among the enforcements We distinguish independent operation and cooperation. Under independent operation, the KFTC and the SPO investigate separately, and a firm's leniency status (e.g., first applicant) with one authority has no direct effect on its status with the other authority. Under cooperation, the authorities recognize leniency status across agencies: if a firm obtains a given rank at one authority, the same rank is honored by the other, so that a single application can secure consistent treatment across authorities. Cooperation also affects detection. With independent in-

[1]This is a reduced-form way to place administrative fines and criminal penalties on a common payoff scale, which is necessary because firms' reporting and collusion decisions are driven by comparisons of expected discounted payoffs. Even when a criminal penalty is non-monetary (e.g., imprisonment of responsible individuals, reputational harm, compliance burdens, debarment, and legal costs), its incentive effect can be summarized by a certainty-equivalent monetary loss that yields the same utility impact as the underlying sanction under the maintained payoff representation. Montag and Tremewan (2020) provide direct support for this approach by eliciting subjects' willingness to pay to avoid non-monetary punishments and showing that non-monetary sanctions can be mapped into monetary units via such valuations.

vestigations and per-authority detection probability ρ, expected sanctions are computed authority-by-authority. With cooperative detection, the probability that at least one authority detects the cartel is $1-(1-\rho)^2 = 2\rho-\rho^2$, which raises the effective detection likelihood relative to ρ for $0 < \rho < 1$. In the sections below, we compare outcomes across enforcement regimes and across amnesty structures, including (i) full immunity for the first self-reporter only, (ii) full immunity for the first and partial immunity for the second, and (iii) the asymmetric regime in which the KFTC grants partial immunity to the second while the SPO does not.

3 Analysis

Throughout, firms use grim-trigger strategies. Let $\Delta \equiv \pi_D - \pi_0 > 0$ and let P denote the expected per-period punishment borne by a cartel member under a given enforcement and leniency regime. If the cartel path yields per-period payoff $\pi_C - P$, the incentive constraint for collusion is

$$\frac{\pi_C - P}{1-\delta} \geqslant \pi_D + \frac{\delta\pi_0}{1-\delta}, \tag{1}$$

which is equivalent to

$$\delta \geqslant \delta(P) \equiv \frac{\pi_D - \pi_C + P}{\pi_D - \pi_0} = \frac{\pi_D - \pi_C + P}{\Delta}. \tag{2}$$

The purpose of our analysis is to evaluate how enforcement design and the leniency framework shape detection and reporting incentives, taking as given that firms may have an incentive to collude. The discount factor δ summarizes firms' patience and the value of future collusive profits. It is firm-specific and not directly controlled by the authority. By contrast, the expected punishment term P is determined by policy-relevant objects: the background detection probability ρ, the administrative fine F, the criminal penalty D, and the mapping between administrative and criminal exposure. Accordingly, rather than treating δ as the main object of interest, we use (2) to express each institutional setting in terms of its implied punishment level P and then characterize how P varies with these policy parameters. This isolates the margins on which the authority can act when designing an enforcement regime and a leniency program.

For each institutional setting, we compute (i) when self-reporting is privately optimal relative to concealment and (ii) the implied collusion threshold $\delta(\cdot)$ for the on-path collusive strategy. We maintain $D = KF$ with $K \geqslant 0$.

For completeness, Appendix A analyzes an additional benchmark in which leniency grants full immunity only to the first self-reporter, and compares independent operation and cooperation under that design.

3.1 Benchmark: No-leniency

In the benchmark, there is no leniency. If there is no enforcement, then $\mathsf{P} = 0$ and collusion is sustainable when

$$\delta \geqslant \delta(0) = \frac{\pi_D - \pi_C}{\Delta}.$$

With a single enforcing authority (KFTC) that detects collusion with probability ρ and imposes fine F, the expected per-period punishment is $\mathsf{P} = \rho \mathsf{F}$ and the collusion condition becomes

$$\delta \geqslant \delta(\rho \mathsf{F}) = \frac{\pi_D - \pi_C + \rho \mathsf{F}}{\Delta}.$$

With two authorities (KFTC and SPO) that operate without leniency, expected per-period punishment depends on whether detection information is shared. Under independent detection and independent sanctioning, $\mathsf{P} = \rho(\mathsf{F} + \mathsf{D}) = \rho(1 + \mathsf{K})\mathsf{F}$. Under cooperative detection such that a detection by either authority triggers both sanctions, the effective detection probability is $1 - (1-\rho)^2 = 2\rho - \rho^2$ and expected punishment is $\mathsf{P} = (2\rho - \rho^2)(\mathsf{F} + \mathsf{D}) = (2\rho - \rho^2)(1 + \mathsf{K})\mathsf{F}$. In both cases, the collusion threshold follows from (2).

3.2 Asymmetric: 100% immunity to the first applicant by both, and 50% to the second by KFTC only

In this regime, the KFTC grants full immunity to the first applicant and a 50% reduction to the second, while the SPO grants full immunity only to the first applicant.

No cooperation This setting corresponds to the current Korean-style institutional environment in which the two programs operate without recognizing each other's leniency status. If all three firms apply for leniency to the KFTC, the expected fine per firm is

$$\mathrm{E}[\mathsf{F} \mid \text{apply to KFTC}] = \frac{1}{3} \cdot 0 + \frac{1}{3} \cdot \frac{1}{2}\mathsf{F} + \frac{1}{3} \cdot \mathsf{F} = \frac{1}{2}\mathsf{F},$$

while expected criminal punishment remains $\rho \mathsf{D} = \rho \mathsf{K} \mathsf{F}$ because the SPO does not recognize the KFTC marker. Hence $\mathsf{P} = \left(\frac{1}{2} + \rho \mathsf{K}\right)\mathsf{F}$ under "collude and report to the

KFTC". If all three firms apply to the SPO, the expected criminal punishment is $\frac{2}{3}\mathsf{D} = \frac{2}{3}\mathsf{KF}$ while the KFTC punishment remains $\rho\mathsf{F}$, so $\mathsf{P} = \left(\rho + \frac{2}{3}\mathsf{K}\right)\mathsf{F}$. If all three apply to both authorities, expected punishment is $\mathsf{P} = \left(\frac{1}{2} + \frac{2}{3}\mathsf{K}\right)\mathsf{F}$.

Under no cooperation, a leniency application is chosen only if it weakly dominates concealment. Under concealment, expected punishment is $\mathsf{P} = \rho(\mathsf{F} + \mathsf{D}) = \rho(1 + \mathsf{K})\mathsf{F}$. Comparing expected punishments shows that reporting to the KFTC dominates concealment if and only if $\rho \geqslant \frac{1}{2}$, while reporting to the SPO dominates concealment only if $\rho \geqslant \frac{2}{3}$. Therefore, on the collusive path, firms conceal for $\rho < \frac{1}{2}$, report only to the KFTC for $\frac{1}{2} \leqslant \rho < \frac{2}{3}$, and report to both for $\rho \geqslant \frac{2}{3}$, yielding the collusion threshold

$$\delta_{AN} = \begin{cases} \delta(\rho(1+\mathsf{K})\mathsf{F}) & \text{if } \rho < \frac{1}{2}, \\ \delta\left(\left(\frac{1}{2} + \rho\mathsf{K}\right)\mathsf{F}\right) & \text{if } \frac{1}{2} \leqslant \rho < \frac{2}{3}, \\ \delta\left(\left(\frac{1}{2} + \frac{2}{3}\mathsf{K}\right)\mathsf{F}\right) & \text{if } \rho \geqslant \frac{2}{3}. \end{cases}$$

Cooperation Under cooperation, the authorities (i) share detection information so that a detection by either triggers both sanctions and (ii) recognize leniency status across agencies. Under concealment, expected punishment is $\mathsf{P} = (2\rho - \rho^2)(1 + \mathsf{K})\mathsf{F}$. Under reporting, a firm that is first before one authority is treated as first before the other, but only the KFTC provides second-in-line relief; thus expected punishment under joint reporting is

$$\mathsf{P} = \frac{1}{2}\mathsf{F} + \frac{2}{3}\mathsf{D} = \left(\frac{1}{2} + \frac{2}{3}\mathsf{K}\right)\mathsf{F}.$$

Self-reporting is preferred to concealment if and only if

$$(2\rho - \rho^2)(1+\mathsf{K})\mathsf{F} \geqslant \left(\frac{1}{2} + \frac{2}{3}\mathsf{K}\right)\mathsf{F},$$

or equivalently

$$2\rho - \rho^2 \geqslant \frac{\frac{1}{2} + \frac{2}{3}\mathsf{K}}{1+\mathsf{K}} \iff \rho \geqslant 1 - \sqrt{\frac{\frac{1}{2} + \frac{1}{3}\mathsf{K}}{1+\mathsf{K}}} \equiv \bar{\rho}_A(\mathsf{K}). \tag{3}$$

Hence the collusion threshold under cooperation is

$$\delta_{AC} = \begin{cases} \delta((2\rho - \rho^2)(1+\mathsf{K})\mathsf{F}) & \text{if } \rho < \bar{\rho}_A(\mathsf{K}), \\ \delta\left(\left(\frac{1}{2} + \frac{2}{3}\mathsf{K}\right)\mathsf{F}\right) & \text{if } \rho \geqslant \bar{\rho}_A(\mathsf{K}). \end{cases}$$

Remark 1 (Self-reporting thresholds under asymmetric leniency: AN vs. AC)**.** *In the asymmetric regime, the no-cooperation environment (AN) requires a relatively high background detection probability for self-reporting to arise: cartel members apply for leniency only if* $\rho \geqslant \frac{1}{2}$*, and they report to both authorities only if* $\rho \geqslant \frac{2}{3}$*. By contrast, under cooperation (AC), self-reporting occurs whenever* ρ *exceeds*

$$\bar{\rho}_A(K) = 1 - \sqrt{\frac{\frac{1}{2} + \frac{1}{3}K}{1 + K}},$$

which satisfies $\bar{\rho}_A(K) \leqslant \frac{1}{2}$ *for all* $K \geqslant 0$ *and lies in* $[1-\sqrt{1/2},\ 1-\sqrt{1/3}] \approx [0.293,\ 0.423]$*. Hence, cooperation strictly expands the set of detection environments in which leniency induces self-reporting: for any* $K > 0$*, there exists an intermediate region* $\rho \in [\bar{\rho}_A(K),\ 1/2)$ *in which AC generates self-reporting while AN yields concealment.*

The comparison has three implications. First, moving from AN to AC reduces the amount of background detection required for leniency to become operative. In particular, when $\rho \in [\bar{\rho}_A(K),\ 1/2)$, the cartel is detected through self-reporting under AC but remains hidden under AN, so the primary welfare gain from cooperation in this region is an increase in expected detection driven by the leniency channel rather than by exogenous monitoring. Second, because $\bar{\rho}_A(K)$ is increasing in K, stronger criminal exposure makes the asymmetric arrangement less effective at inducing reporting even under cooperation: as K rises, the interval $[\bar{\rho}_A(K),\ 1/2)$ shrinks, and in the limit $\bar{\rho}_A(K) \to 1 - \sqrt{1/3} \approx 0.423$. Thus, when criminal penalties are important, cooperation alone may be insufficient unless the amnesty structure is also aligned. Third, AN features a second threshold at $\rho = \frac{2}{3}$ that governs whether firms report to both authorities, which can create partial reporting outcomes (KFTC-only reporting) for $\rho \in [1/2, 2/3)$. Under AC, recognition eliminates this wedge and delivers a unified reporting decision, so cooperation improves predictability for applicants and reduces the scope for strategic forum choice across agencies.

3.3 Symmetric: 100% immunity to the first applicant and 50% to the second by both authorities

In this regime, both authorities grant full immunity to the first applicant and a 50% reduction to the second.

No cooperation Under concealment, expected punishment remains $\mathsf{P} = \rho(1+\mathsf{K})\mathsf{F}$. If all three firms report to both authorities, expected punishment is

$$\mathsf{P} = \frac{1}{2}\mathsf{F} + \frac{1}{2}\mathsf{D} = \frac{1}{2}(1+\mathsf{K})\mathsf{F}.$$

As in the asymmetric case, reporting must dominate concealment to occur on the collusive path. Here,

$$\rho(1+\mathsf{K})\mathsf{F} \geqslant \frac{1}{2}(1+\mathsf{K})\mathsf{F} \quad\Longleftrightarrow\quad \rho \geqslant \frac{1}{2}.$$

Thus firms conceal for $\rho < \frac{1}{2}$ and report to both for $\rho \geqslant \frac{1}{2}$, and the collusion threshold is

$$\delta_{SN} = \begin{cases} \delta(\rho(1+\mathsf{K})\mathsf{F}) & \text{if } \rho < \frac{1}{2}, \\ \delta\big(\frac{1}{2}(1+\mathsf{K})\mathsf{F}\big) & \text{if } \rho \geqslant \frac{1}{2}. \end{cases}$$

Cooperation Under cooperation, concealment yields expected punishment $\mathsf{P} = (2\rho - \rho^2)(1+\mathsf{K})\mathsf{F}$, while reporting yields $\mathsf{P} = \frac{1}{2}(1+\mathsf{K})\mathsf{F}$ because first and second ranks are recognized across agencies and both authorities grant the same relief. Reporting dominates concealment if and only if

$$(2\rho - \rho^2)(1+\mathsf{K})\mathsf{F} \geqslant \frac{1}{2}(1+\mathsf{K})\mathsf{F} \quad\Longleftrightarrow\quad 2\rho - \rho^2 \geqslant \frac{1}{2} \quad\Longleftrightarrow\quad \rho \geqslant 1 - \sqrt{\frac{1}{2}}.$$

Therefore,

$$\delta_{SC} = \begin{cases} \delta((2\rho - \rho^2)(1+\mathsf{K})\mathsf{F}) & \text{if } \rho < 1 - \sqrt{\frac{1}{2}}, \\ \delta\big(\frac{1}{2}(1+\mathsf{K})\mathsf{F}\big) & \text{if } \rho \geqslant 1 - \sqrt{\frac{1}{2}}. \end{cases}$$

Remark 2 (Self-reporting thresholds under symmetric second-in-line relief: SN vs. SC)**.** *In the symmetric regime, without cooperation (SN) cartel members self-report only if* $\rho \geqslant \frac{1}{2}$*, because concealment yields expected punishment* $\rho(\mathsf{F}+\mathsf{D})$ *while joint reporting yields* $\frac{1}{2}(\mathsf{F}+\mathsf{D})$*. Under cooperation (SC), concealment yields expected punishment* $(2\rho - \rho^2)(\mathsf{F}+\mathsf{D})$ *while reporting still yields* $\frac{1}{2}(\mathsf{F}+\mathsf{D})$*, so self-reporting occurs if and only if*

$$2\rho - \rho^2 \geqslant \frac{1}{2} \quad\Longleftrightarrow\quad \rho \geqslant 1 - \sqrt{\frac{1}{2}} \approx 0.293.$$

Thus, cooperation strictly lowers the detection threshold required for self-reporting from $\frac{1}{2}$ *to* $1 - \sqrt{1/2}$*, and this threshold is independent of* K*.*

The implication is that cooperation is most reliable when the amnesty structure is aligned across authorities: it expands the range of environments in which leniency induces reporting (from $\rho \geqslant 0.5$ to $\rho \geqslant 0.293$) and does so without becoming harder to satisfy when criminal penalties are more severe. This makes SC the most robust design for generating self-reporting at moderate detection rates.

3.4 Proposition

Proposition 1 (Self-reporting thresholds across regimes)**.** *Consider a triopoly with two authorities (KFTC and SPO). Let each authority have baseline detection probability* $\rho \in (0, 1)$ *and let* $D = KF$ *with* $K \geqslant 0$*. Compare concealment to (symmetric) self-reporting on the collusive path.*

(i) ***No cooperation.*** *Under both the asymmetric regime (100% to the first by both, 50% to the second by the KFTC only) and the symmetric regime (100% to the first and 50% to the second by both), self-reporting occurs on the collusive path if and only if*

$$\rho \geqslant \frac{1}{2}.$$

(ii) ***Cooperation, symmetric framework.*** *Under cooperation with the symmetric framework, self-reporting occurs on the collusive path if and only if*

$$\rho \geqslant 1 - \sqrt{\frac{1}{2}} \approx 0.293,$$

and this threshold does not depend on K*.*

(iii) ***Cooperation, asymmetric framework.*** *Under cooperation with the asymmetric framework, self-reporting occurs on the collusive path if and only if*

$$\rho \geqslant \bar{\rho}_A(K) \equiv 1 - \sqrt{\frac{\frac{1}{2} + \frac{1}{3}K}{1 + K}},$$

where $\bar{\rho}_A(K)$ *is increasing in* K *and satisfies*

$$1 - \sqrt{\frac{1}{2}} \leqslant \bar{\rho}_A(K) \leqslant 1 - \sqrt{\frac{1}{3}} \approx 0.423.$$

The proposition implies the following. First, cooperation lowers the detection probability required for self-reporting: the cutoff shifts from $\rho = \frac{1}{2}$ (no cooperation) to $\rho = 1 - \sqrt{1/2}$

(cooperation with the symmetric framework) and to $\rho = \bar{\rho}_A(K)$ (cooperation with the asymmetric framework). Second, under cooperation, the symmetric framework yields a cutoff that does not depend on K, whereas the asymmetric framework yields a cutoff that increases with K. Hence, for a given $\rho < \frac{1}{2}$, cooperation induces self-reporting under the symmetric framework for a wider set of K than under the asymmetric framework.

4 Policy Implications for Leniency and Detection

4.1 Detection probability as a scarce policy instrument

The detection probability ρ plays a central role in cartel outcomes because it governs both the expected punishment under concealment and the credibility of leniency as an escape option. Harrington (2005) formalizes this point in a dynamic cartel model by treating detection as an exogenous hazard that can depend on observable market outcomes and by showing that cartel behavior is shaped by the perceived mapping from conduct to detection risk. A practical implication of Harrington (2005) is that ρ is not only important but also difficult to pin down and to influence in a targeted way: detection reflects multiple channels (including complaints and whistleblowing) and the available evidence on how suspicious events translate into investigations is limited, so policy discussion naturally focuses on ρ as a reduced-form object that summarizes investigative capacity and institutional arrangements rather than as a parameter that can be engineered precisely.

Empirical estimates suggest that ρ is not high in practice. Using U.S. data from 1961 to 1988, Bryant and Eckard (1991) estimates a detection rate between 13% and 17%. Using European Union data from 1969 to 2007, Combe et al. (2008) estimates a detection rate of 12.9%–13.3%. Similarly, Ormosi (2014) estimates that the EU detection rate over 1985–2009 lies in the range of 10%–20%. These magnitudes imply that, while increasing ρ can improve outcomes by inducing self-reporting in the short run and by deterring collusion in the long run, relying on large increases in ρ may be costly and slow. This makes institutional changes that reduce the self-reporting threshold with respect to ρ directly relevant for policy design.

Our model delivers a transparent link between market structure and the detection probability needed for self-reporting. In the symmetric regime under cooperation, when there are n colluding firms, the self-reporting cutoff is

$$\rho = \left(1 - \sqrt{\frac{3}{2n}}\right)^{n-2}. \tag{4}$$

The median number of participating firms in a cartel is reported to be around 4–5 (Connor, 2003; Levenstein and Suslow, 2004). For $n = 4$ and $n = 5$, the implied cutoffs are lower than in the triopoly benchmark, consistent with the general observation that larger cartels generate a stronger race-to-report effect. However, the asymmetric framework raises the cutoff relative to the symmetric framework because second-in-line applicants remain exposed to the criminal component, so the level of ρ suggested by the empirical literature may be insufficient to secure self-reporting under asymmetry even when it would be sufficient under symmetry. This comparison is the sense in which leniency design can substitute for costly increases in detection capability.

4.2 Why cooperation may fail under asymmetric leniency

A central implication of the model is that the effectiveness of leniency hinges on the background detection probability ρ. In practice, ρ is a policy-relevant object: it is shaped by investigative resources, screening capacity, and inter-agency information sharing, and raising ρ is typically costly. The sanction magnitudes are also policy objects, summarized by the administrative fine F and the monetary-equivalent criminal penalty $D = KF$ following Montag and Tremewan (2020). The parameter K captures the severity of criminal exposure relative to the administrative fine and determines how much weight firms place on the criminal component when comparing expected discounted payoffs. By contrast, the discount factor δ is firm-specific and not directly observed. For policy design, it is therefore natural to focus on the threshold value of ρ required for cartel members to self-report, and on how that threshold varies with K under alternative institutional frameworks. The title of this subsection reflects that cooperation can raise detection and still fail to trigger self-reporting when the leniency framework is asymmetric.

Under cooperation, concealment implies expected per-period punishment $(2\rho - \rho^2)(F + D)$. In the symmetric regime, self-reporting implies expected punishment $\frac{1}{2}(F + D)$, so the self-reporting condition is $(2\rho - \rho^2)(F + D) \geqslant \frac{1}{2}(F + D)$, equivalently $\rho \geqslant 1 - \sqrt{1/2}$. The cutoff is constant in K because both concealment and self-reporting scale with the total sanction $F + D = (1 + K)F$. In the asymmetric regime, self-reporting implies expected punishment $\frac{1}{2}F + \frac{2}{3}D$, so the self-reporting condition is $(2\rho - \rho^2)(F + D) \geqslant \frac{1}{2}F + \frac{2}{3}D$,

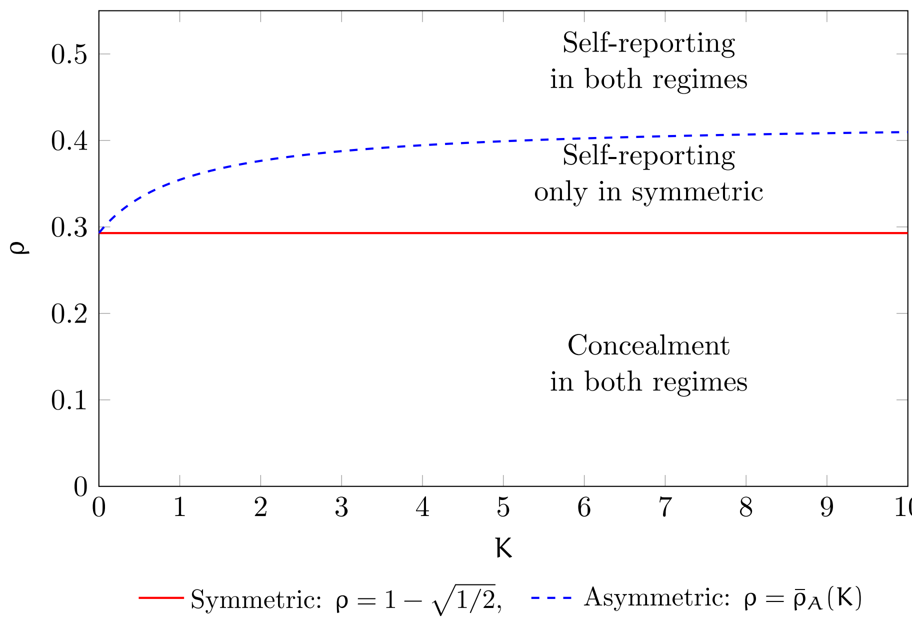

Figure 1: Self-reporting thresholds under cooperation. The red solid line is the symmetric cutoff $\rho = 1 - \sqrt{1/2}$. The blue dashed line is the asymmetric cutoff $\rho = \bar{\rho}_A(K) = 1 - \sqrt{\frac{\frac{1}{2}+\frac{1}{3}K}{1+K}}$.

equivalently $\rho \geqslant \bar{\rho}_A(K) \equiv 1 - \sqrt{\frac{\frac{1}{2}+\frac{1}{3}K}{1+K}}$, which increases in K. Figure 1 shows that the symmetric cutoff is uniformly lower: for any K, the symmetric regime requires a weakly smaller ρ to induce self-reporting than the asymmetric regime.

Figure 1 also clarifies what it means for cooperation to "fail" under asymmetric leniency. Cooperation raises the expected punishment under concealment by replacing ρ with $2\rho - \rho^2$. However, cooperation does not by itself determine the expected punishment under self-reporting, which depends on how the two authorities treat applicant ranks. Under the asymmetric regime, the second applicant receives partial relief from F but no relief from D. When K is large, this raises the expected punishment under self-reporting relative to concealment at a given ρ, so a larger ρ is required for concealment to be sufficiently unattractive. The region between the red and blue curves therefore corresponds to environments in which cooperation would induce self-reporting under a symmetric framework but does not induce self-reporting under an asymmetric framework.

This comparison has a direct policy interpretation. A lower cutoff means that self-reporting can be induced with weaker investigative capacity or lower enforcement spending, because the authority does not need to raise ρ as much for leniency to become privately attractive. Under cooperation, moving from the asymmetric to the symmetric regime shifts the required detection probability from $\bar{\rho}_A(K)$ to $1 - \sqrt{1/2}$, which is strictly lower for $K > 0$. The wedge between the two curves therefore represents enforcement environments in which a cooperative system yields applications under a symmetric framework but yields no applications under an asymmetric framework.

The dependence on K under the asymmetric regime explains why cooperation may fail even when criminal enforcement is strengthened. When K is larger, criminal exposure accounts for a larger share of expected punishment. Under the asymmetric regime, the second applicant remains fully exposed to D, so self-reporting does not provide proportional relief on the criminal component. By contrast, concealment remains disciplined by detection: the criminal component is paid only with probability $2\rho - \rho^2$. As K increases, the expected cost of being second rises relative to the expected cost of concealment at a given ρ, and cartel members require a higher ρ before self-reporting dominates concealment. In this sense, increasing K can move the economy from the region where cooperation induces self-reporting into the region where cooperation does not.

This result can appear counterintuitive if it is read as suggesting that a policy maker should reduce ρ in order to obtain more self-reporting. The mechanism is the opposite. A reduction in ρ lowers the expected punishment from concealment and therefore weakens the incentive to self-report in both frameworks. Lowering ρ also lowers expected detection directly. Hence, reducing ρ cannot be a policy response to the K-dependence of the asymmetric cutoff. The comparative statics indicate that, under asymmetry, higher K shifts the self-reporting threshold upward, so maintaining self-reporting would require increasing ρ, which is costly. The symmetric regime avoids this tradeoff because the self-reporting cutoff does not move with K and is uniformly lower.

The model therefore points to an institutional implication: when criminal exposure is substantial, cooperation that recognizes ranks does not guarantee self-reporting unless the relief structure is comparable across authorities. If the objective is to induce self-reporting without relying on large increases in ρ, the symmetric regime achieves this by keeping the threshold low and stable in K. In a cooperative environment, the main gain from moving to symmetry is that it makes leniency effective at moderate detection probabilities even when the criminal component is quantitatively important in firms' payoff comparisons.

4.3 Detection policy as an optimization problem

This subsection treats ρ as a choice variable. The reason is that ρ is shaped by investigative resources, screening capacity, and inter-agency arrangements, and raising ρ is typically costly. By contrast, the discount factor δ is firm-specific and not directly observed. It is therefore natural to formulate policy in terms of how the authority selects ρ, taking the firms' willingness to collude as given. Consistent with the discussion in Section 4.1, ρ affects outcomes both through the likelihood of punishment under concealment and through whether leniency induces self-reporting, which is the key channel emphasized in the analysis above.

The size of the wedge is relevant because empirical work suggests that cartel detection probabilities are typically low. Using U.S. data from 1961 to 1988, Bryant and Eckard (1991) estimates a detection rate between 13% and 17%. Using European Union data from 1969 to 2007, Combe et al. (2008) estimates a detection rate of 12.9%–13.3%. Similarly, Ormosi (2014) estimates that the EU detection rate over 1985–2009 lies in the range of 10%–20%. These estimates are below the region in Figure 1 in which self-reporting is induced under the symmetric framework. The model is stylized, including the maintained triopoly assumption, and the cutoff generally falls as the number of cartel members increases. Nevertheless, the empirical evidence indicates that detection is not high in practice, so institutional design that reduces the required ρ is a first-order concern. In particular, it is unlikely that self-reporting can be obtained through an asymmetric framework unless detection capability increases substantially.

In our analysis, the self-reporting cutoff ρ in the symmetric regime, when there are n colluding firms in the market, is given by

$$\rho \ = \ (1 - \sqrt{\frac{3}{2n}})^{n-2}. \tag{5}$$

The median number of participating firms in a cartel is reported to be around 4–5 generally (Connor, 2003; Levenstein and Suslow, 2004). Although our discussion focuses on the triopoly case ($n = 3$), for which $\rho = 0.293$, the implied cutoff is $\rho = 0.150255$ when $n = 4$ and $\rho = 0.092516$ when $n = 5$. These values are broadly consistent with the magnitudes estimated in previous empirical literature and demonstrate that, as the number of cartel participants increases, the detection-probability cutoff required to induce self-reporting becomes lower.

Let $C(\rho)$ denote the cost of achieving detection probability ρ, with $C'(\rho) > 0$ and $C''(\rho) \geqslant 0$. Let $B(\rho)$ denote the benefit from setting ρ. The authority chooses $\rho \in [0, 1]$

to solve

$$\max_{\rho\in[0,1]} \mathsf{B}(\rho) - \mathsf{C}(\rho). \tag{6}$$

The benefit function is abstract, but the preceding analysis suggests two components that are relevant in the present setting.

In the short run, take as given that there exist colluding firms with sufficiently high δ so that collusion is feasible absent changes in enforcement. A higher ρ improves outcomes through two channels. One channel is whether leniency induces self-reporting. Under cooperation, self-reporting occurs only if ρ exceeds the regime-specific threshold: $\rho \geqslant 1 - \sqrt{1/2}$ in the symmetric regime and $\rho \geqslant \bar{\rho}_{\mathsf{A}}(\mathsf{K})$ in the asymmetric regime. The other channel is the expected punishment under concealment, which under cooperation equals $(2\rho - \rho^2)(\mathsf{F} + \mathsf{D})$. A reduced-form representation that captures both channels is

$$\mathsf{B}^{\mathsf{SR}}(\rho) = \mathfrak{b}_1 \cdot \mathbb{1}\{\rho \geqslant \rho^*\} + \mathfrak{b}_2 \cdot (2\rho - \rho^2)(\mathsf{F} + \mathsf{D}),$$

where $\mathfrak{b}_1, \mathfrak{b}_2 > 0$ and ρ^* is the relevant self-reporting cutoff. The indicator term captures a discrete gain when self-reporting occurs, while the second term captures the continuous gain from higher expected punishment when firms conceal.

In the long run, short-run enforcement outcomes affect the prevalence of collusion by changing firms' continuation values and compliance choices. In the model, sustainability depends on δ, so enforcement that increases detection and punishment can reduce the set of environments in which collusion is sustainable. In reduced form, let $\Pr(\text{collusion} \mid \rho)$ denote the prevalence of collusion under detection probability ρ, and suppose $\Pr(\text{collusion} \mid \rho)$ is decreasing in ρ. A long-run component can then be written as

$$\mathsf{B}^{\mathsf{LR}}(\rho) = \mathfrak{b}_3 \cdot \left[-\Pr(\text{collusion} \mid \rho)\right],$$

with $\mathfrak{b}_3 > 0$. The total benefit is $\mathsf{B}(\rho) = \mathsf{B}^{\mathsf{SR}}(\rho) + \mathsf{B}^{\mathsf{LR}}(\rho)$.

The institutional regime matters for the choice of ρ because it shifts the location of the self-reporting cutoff. Under cooperation, the symmetric regime has a lower and K-independent cutoff $1 - \sqrt{1/2}$, while the asymmetric regime has a higher cutoff $\bar{\rho}_{\mathsf{A}}(\mathsf{K})$ that increases with K. If self-reporting generates an incremental benefit and $\mathsf{C}(\rho)$ is increasing, then lowering the cutoff raises $\mathsf{B}(\rho)$ for intermediate values of ρ and can move the maximizer of (6) downward. In this sense, the symmetric regime may support a lower optimal detection rate than the asymmetric regime, because it can make self-reporting operative at a lower ρ and therefore at a lower enforcement cost.

4.4 What type of cooperation is required?

In the analysis above, "cooperation" is not meant to require full integration of investigations or full sharing of leniency materials. The mechanism operates through a narrower channel: whether a firm that approaches one authority can predict the effective reduction in total expected punishment once the other authority is taken into account. In the model, this is captured by whether leniency rank (first or second) is recognized across authorities, so that a firm that secures a position at one authority obtains the corresponding treatment at the other.

This distinction matters because cooperation has at least two conceptually separate components. One component is cooperation in detection, which increases the probability that concealment is punished from ρ to $2\rho - \rho^2$ under the maintained independence of each authority's detection technology. This component affects the expected punishment from concealment. The other component is cooperation in administering leniency, which determines whether the expected punishment under self-reporting is computed on a single, predictable rank across authorities or on separate ranks that may differ across authorities. The results on the self-reporting threshold are driven primarily by the second component.

From a policy perspective, rank recognition can be implemented with a minimal informational footprint. It requires a verifiable marker system (e.g., timestamps and applicant identity) and a procedure to confirm whether a marker has been granted and which rank it implies, without requiring disclosure of the content of the submission. In the context of the model, what is needed is the ability of the second authority to condition its treatment on whether the applicant is first or second in the combined system. By contrast, broader information sharing about the underlying cartel conduct is not required for the threshold comparisons emphasized in Figure 1.

This also clarifies why cooperation may fail under asymmetric leniency even if detection cooperation is strong. Increasing detection cooperation raises the expected punishment from concealment, but if the leniency rank is not recognized or if the relief structure differs across authorities, the expected punishment under self-reporting can remain high for non-first applicants. In that case, cooperation can raise expected punishment and still leave concealment privately optimal for intermediate values of ρ.

4.5 Sanction composition and reporting incentives

The model distinguishes between the level of sanctions and the composition of sanctions. The level of sanctions is summarized by $\mathsf{F} + \mathsf{D}$, while the composition is summarized by K through $\mathsf{D} = \mathsf{KF}$. These two dimensions have different implications for reporting incentives.

Under the symmetric regime with cooperation, both concealment and self-reporting scale with the total sanction $\mathsf{F}+\mathsf{D}$. Concealment implies expected per-period punishment $(2\rho - \rho^2)(\mathsf{F} + \mathsf{D})$, while self-reporting implies expected punishment $\frac{1}{2}(\mathsf{F} + \mathsf{D})$. The self-reporting threshold therefore depends only on ρ and not on K. Changes in K shift the magnitude of expected punishment, but they do not shift the detection probability required for self-reporting to occur.

Under the asymmetric regime with cooperation, the composition of sanctions matters because leniency does not reduce the criminal component for the second applicant. Self-reporting implies expected punishment $\frac{1}{2}\mathsf{F}+\frac{2}{3}\mathsf{D} = \left(\frac{1}{2} + \frac{2}{3}\mathsf{K}\right)\mathsf{F}$, while concealment implies $(2\rho - \rho^2)(\mathsf{F} + \mathsf{D}) = (2\rho - \rho^2)(1 + \mathsf{K})\mathsf{F}$. The self-reporting threshold becomes $\rho \geqslant \bar{\rho}_{\mathsf{A}}(\mathsf{K})$, which increases in K. Holding fixed the total sanction $\mathsf{F} + \mathsf{D}$, shifting weight from F to D raises the punishment associated with being second under self-reporting without changing the fact that concealment avoids D with probability $1-(2\rho-\rho^2)$. As a result, higher K raises the detection probability required for self-reporting under the asymmetric regime.

This comparative statics has a direct policy interpretation. Increasing the severity of criminal exposure (higher K) without changing the relief structure can reduce the likelihood of self-reporting under an asymmetric regime unless detection probability rises. By contrast, under a symmetric regime, the same increase in K does not tighten the self-reporting condition. This is the sense in which symmetry makes leniency robust to changes in the composition of sanctions, while asymmetry makes reporting incentives sensitive to the relative weight placed on criminal punishment.

5 Conclusion

This paper studies cartel detection when two authorities operate separate leniency programs, with a focus on the incentives created by independent operation versus cooperation and by symmetric versus asymmetric second-in-line relief. In a repeated triopoly model with grim-trigger strategies, firms compare expected discounted payoffs from concealment and self-reporting, where the KFTC imposes an administrative fine F and the

SPO imposes a criminal penalty $\mathsf{D} = \mathsf{KF}$. The policy-relevant object is the background detection probability ρ, which is shaped by enforcement resources and institutional arrangements, while the discount factor δ is firm-specific and not directly observed.

The main findings concern the self-reporting threshold. Without cooperation, self-reporting on the collusive path requires $\rho \geqslant 1/2$ under both the symmetric and asymmetric amnesty structures considered. Under cooperation with a symmetric framework, the cutoff falls to $\rho \geqslant 1 - \sqrt{1/2} \approx 0.293$ and is independent of K. Under cooperation with an asymmetric framework, the cutoff is $\rho \geqslant \bar{\rho}_{\mathsf{A}}(\mathsf{K})$, which increases in K and approaches $1 - \sqrt{1/3} \approx 0.423$ as K rises. The economic mechanism is that asymmetry leaves the second applicant fully exposed to the criminal component, so self-reporting does not deliver proportional relief as criminal exposure becomes more important, and cooperation in detection alone does not offset this effect at moderate ρ.

The policy implication is that cooperation can be complemented by amnesty alignment. A symmetric second-in-line relief structure reduces the detection probability required for leniency to induce self-reporting and avoids a regime in which stronger criminal exposure requires higher detection effort to preserve reporting incentives. The analysis also clarifies that the form of cooperation that matters for the self-reporting margin is rank recognition across authorities. A marker-verification procedure that allows consistent treatment of first and second applicants can implement this channel without requiring full sharing of leniency materials. In addition, when enforcement is costly, a symmetric framework can support a lower optimal detection rate in a reduced-form choice problem, because it makes the self-reporting benefit operative at a lower ρ.

The model is intentionally stylized and abstracts from several features that may matter for quantitative assessment, including heterogeneity in firms, asymmetric evidence quality across authorities, and procedural constraints that affect the timing of applications and investigations. These extensions are natural directions for future work, but the qualitative message is robust: dual-agency leniency can weaken self-reporting when programs are not aligned, and cooperation is most effective when it includes rank recognition and a symmetric structure of relief for early applicants.

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Appendix

A Additional Benchmark

This appendix develops an additional benchmark that is useful for interpreting the main analysis. The main text focuses on the setting in which second-in-line relief is available and compares symmetric and asymmetric relief structures under alternative forms of inter-agency interaction. Here we instead consider a simpler leniency design that grants full immunity only to the first self-reporter. The purpose is to isolate how the interaction between two authorities affects incentives when the leniency instrument itself is minimal, and to provide a transparent reference point for how the required detection environment changes when enforcement is conducted by a single authority versus two authorities that either operate independently or cooperate. The results in this appendix also clarify why cooperation can lower the detection burden required for leniency to induce reporting even when the relief structure is unchanged.

A.1 Symmetric Leniency: Full Immunity for First Self-Reporter

In this subsection, we explore the scenario where two regulatory authorities, the KFTC and the SPO, are involved in enforcing anti-collusion policies. In practice, KFTC imposes fines for collusion, while the SPO determines whether to pursue criminal charges. In our model, we represent the fines imposed for collusion as F and the severity of criminal penalties as D. Following the framework of Montag and Tremewan (2020), we assume $\mathsf{D} = \mathsf{KF}$, where $\mathsf{K} \in \mathbb{R}$.[2] For simplicity and to focus on the structure of leniency programs, we also assume that the probability of detecting collusion (ρ) is the same for both the KFTC and the SPO.

We then examine two scenarios: one where the KFTC and the SPO act independently, and another where they cooperate in detecting and penalizing collusion.

A.1.1 Independent operation of the KFTC and the SPO in detecting collusion and granting leniency

In the presence of a leniency program, we can consider three potential strategies: (1) *Collude & Conceal* (2) *Collude & Self-report* (i.e., apply for leniency) and (3) *Grim*

[2] While it is not possible to substitute criminal penalties with a monetary payment in reality, Montag and Tremewan (2020) investigate individuals' willingness to pay to avoid criminal penalties by converting these penalties into monetary terms, and we have incorporated this into our model.

Trigger. For collusion to be viable, the payoffs from either (1) or (2) must be greater than from (3). Therefore, we examine the conditions under which collusion can occur in cases (1) and (2). Additionally, for the leniency application to be meaningful, the payoff from (2) must exceed that of (1).

[***Collude & Conceal***] Let us first examine the strategy of colluding without applying for leniency, concealing the collusion. Since the two regulatory authorities operate independently, the expected fine and expected criminal penalty, taking into account the probability of detection, are ρF and ρD, respectively. The condition for sustaining collusion is as follows:

$$\frac{1}{1-\delta}\left(\pi_C - \rho(F + D)\right) \geqslant \pi_D + \frac{\delta}{1-\delta}\pi_0 \quad (3)$$

In the benchmark model, when only the KFTC enforces anti-collusion regulations, the expected fine is ρF. However, when both the KFTC and the Prosecutor's Office regulate collusion, the expected punishment increases to $\rho(F + D)$. This implies that implementing both fines and criminal penalties lowers the expected profit from actual collusion. Let δ^{***} represent the discount factor that satisfies condition (3), and when compared to the discount factor from case (2), the required δ for collusion to occur becomes larger ($\delta^{***} > \delta^{**}$). In other words, the joint enforcement of fines and criminal penalties makes it more difficult to sustain collusion compared to a single regulatory authority.

[***Collude & Self-report***] Now consider the payoff when a firm chooses the Collude & Self-report strategy. First, if the firm only self-reports to the KFTC, one of the three firms in the triopoly will receive immunity from fines, resulting in an expected fine of $\frac{2}{3}F$. However, since the prosecutor operates independently, the expected criminal penalty is ρD. Therefore, the expected payoff in each period is $\pi_C - \frac{2}{3}F - \rho D$. Similarly, if the firm self-reports only to the prosecutor, the expected payoff is $\pi_C - \rho F - \frac{2}{3}D$. If the firm self-reports to both the KFTC and the prosecutor, the fines and penalties are determined independently, so the expected payoff in each period is $\pi_C - \frac{2}{3}F - \frac{2}{3}D$. If $\rho \geqslant \frac{2}{3}$, the payoff from self-reporting to both authorities is greater than that from reporting to just one. Otherwise, the firm will report to only one authority. Thus, the conditions under which the Collude & Self-report strategy is feasible depend on ρ and are as follows:

$$\frac{1}{1-\delta}\left(\pi_C - \frac{2}{3}F - \rho D\right) \text{ or } \quad \frac{1}{1-\delta}\left(\pi_C - \rho F - \frac{2}{3}D\right) \geqslant \pi_D + \frac{\delta}{1-\delta}\pi_0 \quad \text{if} \quad \rho < \frac{2}{3} \quad (4)$$

$$\frac{1}{1-\delta}\left(\pi_C - \frac{2}{3}F - \frac{2}{3}D\right) \geqslant \pi_D + \frac{\delta}{1-\delta}\pi_0 \quad \text{if} \quad \rho \geqslant \frac{2}{3} \quad (5)$$

For the leniency policy to be effective in detecting collusion, the payoff from the Collude and Self-report strategy must be greater than that from the Collude and Conceal strategy. Specifically, the following conditions must hold: $\pi_C - \frac{2}{3}(F+D) \geqslant \pi_C - \rho(F+D)$, or $\pi_C - \frac{2}{3}F - \rho D \geqslant \pi_C - \rho(F+D)$, or $\pi_C - \rho F - \frac{2}{3}D \geqslant \pi_C - \rho(F+D)$. When $\rho \geqslant \frac{2}{3}$, the payoff from the Collude and Self-report strategy is always greater, making the leniency application a viable method for detecting collusion. On the other hand, when the probability of detection is insufficient ($\rho < \frac{2}{3}$), even with the existence of leniency policy, firms may lack the incentive to self-report and continue to adhere to the Collude and Conceal strategy.

A.1.2 Cooperation between the KFTC and the SPO in detecting collusion and administering leniency

Now it is the case where the two regulatory authorities cooperate in detecting collusion and administering the leniency program. As previously mentioned, we assume the cartel detection rate of both the KFTC and the Prosecutor's Office is ρ. In this case, the probability that collusion is detected by either or both authorities is $1-(1-\rho)^2$. Therefore, the detection rate rises to $2\rho - \rho^2$, which is higher than the detection rate of ρ when the authorities operate independently. Except for the case where the detection rate is 1 (i.e., when all collusion is perfectly detected), the detection rate with cooperation is always higher than when the authorities act independently ($2\rho - \rho^2 > \rho$ for $0 < \rho < 1$).
[***Collude & Conceal***] Compared to Section 3.2.1, the increase in the detection rate due to the cooperation between the regulatory authorities ($2\rho - \rho^2$) raises the expected fine and criminal penalty, thereby reducing the expected payoff from the Collude and Conceal strategy. Specifically, if a firm colludes and does not apply for leniency, the expected payoff in each period is $\pi_C - (2\rho - \rho^2)(F + D)$. The condition for sustaining collusion under the Collude and Conceal strategy is given by:

$$\frac{1}{1-\delta}\left(\pi_C - (2\rho - \rho^2)(F + D)\right) \geqslant \pi_D + \frac{\delta}{1-\delta}\pi_0 \quad (6)$$

Let δ^{****} be the threshold discount rate that satisfies (6). Since the firm's expected payoff is lower when the KFTC and the Prosecutor's Office cooperate than when they operate independently, the discount rate required for collusion is higher. Therefore, when compared to the threshold discount rate in Section 3.2.1's condition (3) (δ^{***}), we have $\delta^{****} > \delta^{***}$. In conclusion, cooperation between the KFTC and the Prosecutor's Office makes it more difficult to sustain collusion than when the two authorities operate independently.

[***Collude & Self-report***] When the regulatory authorities cooperate in administering their leniency policies, receiving leniency from one authority as the first self-reporter is also recognized by the other authority. Therefore, by applying to just one of the two authorities (the KFTC or the Prosecutor's Office), a firm can receive immunity from both. In this case, the expected punishment becomes $\frac{2}{3}(\mathsf{F} + \mathsf{D})$. As a result, the condition for sustaining collusion is given by:

$$\frac{1}{1-\delta}\left(\pi_{\mathsf{C}} - \frac{2}{3}\mathsf{F} - \frac{2}{3}\mathsf{D}\right) \geqslant \pi_{\mathsf{D}} + \frac{\delta}{1-\delta}\pi_0 \quad (7)$$

Thus, when leniency applications are automatically recognized by the other regulatory authority, the option of applying to only one of the two authorities can be eliminated, considering the payoff advantages or disadvantages based on the cartel detection rate.

As shown in Section 3.2.1, for the leniency program to be effective in detecting collusion, the payoff from the Collude and Self-report strategy must be greater than that from the Collude and Conceal strategy. Specifically, $\pi_{\mathsf{C}} - \frac{2}{3}\mathsf{F} - \frac{2}{3}\mathsf{D} \geqslant \pi_{\mathsf{C}} - (2\rho - \rho^2)(\mathsf{F} + \mathsf{D})$, which implies $\rho \geqslant 1 - \sqrt{\frac{1}{3}} = 0.423$. Therefore, the leniency policy becomes meaningful for detecting collusion when the cartel detection rate is 0.423 or higher.