Development Studies Series DS25-03

Single- vs. Multi-Jurisdictional Leniency Policies: An Experiment

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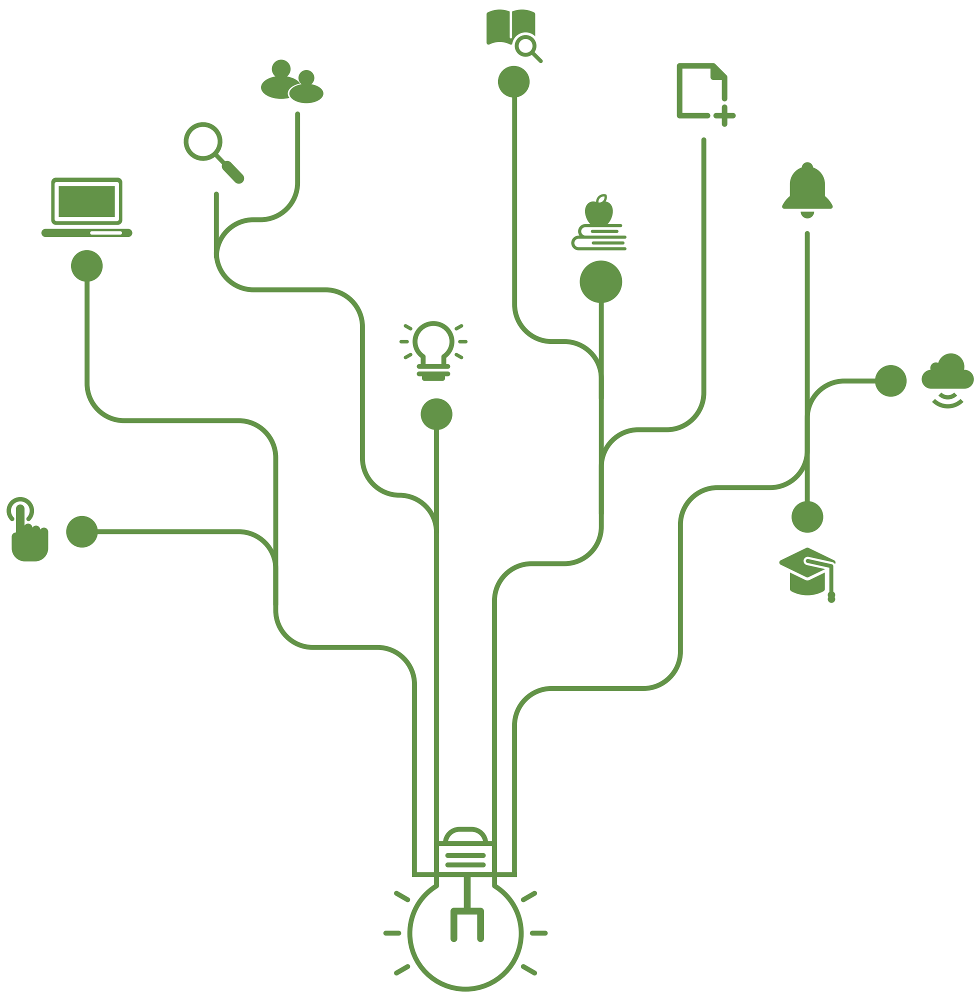

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February 25, 2025

Abstract

As multinational corporations have become more common, the need for a multi-jurisdictional leniency program that allows antitrust authorities to recognize leniency applications submitted to other antitrust authorities has recently emerged. This paper employs a laboratory experiment to examine how multi-jurisdictional leniency policies affect cartel formation, deterrence, and detection compared with a single-jurisdictional policy. The findings confirm the deterrent effect of leniency policies on cross-border cartels but show that multi-jurisdictional leniency does not necessarily increase leniency applications. In particular, when antitrust authorities do not mutually guarantee full immunity for firms that self-report to different authorities, self-reporting declines, decreasing cartel exposure and increasing the number of successful cartels that are formed but remain unexposed.

Keywords: Antitrust, Cartel, Leniency policy, Jurisdiction, Experiment

JEL: C9 K21 L2 L4 L44

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1 Introduction

Investigating collusion is challenging. It is often conducted in secrecy, and companies may use their market influence to obstruct investigations, making it difficult for investigators to gather evidence to prove collusion. Leniency programs, which exempt the first self-reporting member of a cartel from collusion-related sanctions, are a way for investigators to incentivize cartel instability. The United States introduced the first leniency program in 1978, and in 1994 it began guaranteeing complete immunity to the first self-reporter, which increased the rate of cartel detection. Since then, leniency programs have been adopted by various countries, and as of 2024, 79 regulatory agencies operated such programs.[1]

Regulatory authorities in various countries initially operated under a "single-jurisdictional leniency" system, which granted immunity from cartel-related penalties to the first member within its jurisdiction who voluntarily reported. At that time, markets were typically national or smaller in scale, which meant cross-border cartels were uncommon, and investigations could be handled by one antitrust regulatory agency. Since then, there has been a decline in both the number of leniency applications and self-reporting of cartel involvement (OECD, 2023).[2] As markets have become more transnational, cross-border cartels have emerged, meaning that a single market may now be subject to multiple regulatory authorities, potentially undermining the effectiveness of such authorities' leniency programs.

Under a single-jurisdictional leniency system, even if a cartel member self-reports to one regulatory authority and is granted leniency, there is no assurance that regulatory authorities in other jurisdictions will offer a similar penalty reduction. This lack of assurance not only decreases the incentive to self-report but may actually strengthen the cohesiveness of a cartel. Consequently, the OECD has proposed a multi-jurisdictional leniency program, which would differ from a single-jurisdictional system in two key ways. First, it would facilitate cooperative cartel investigations among participating countries. Second, it would allow self-reporting to a regulatory authority in one country to be recognized by authorities in other countries, linking leniency across jurisdictions.

A switch from a single-jurisdictional leniency program to multi-jurisdictional leniency programs would lead to both an increase and, under certain conditions, a decrease in leniency applications. Under a multi-jurisdictional leniency regime, cartel members that choose not to apply for leniency face fines imposed by multiple jurisdictions at once, resulting in a higher expected penalty compared with a single-jurisdictional setting. The increased risk of penalties may encourage firms to apply for leniency. However, if a multi-jurisdictional leniency program does not guarantee full immunity across all jurisdictions, self-reporting to one competition authority may expose collusive conduct to others, potentially discouraging leniency applications.

[1] See https://www.internationalcompetitionnetwork.org/working-groups/cartel/leniency/leniency-links/

[2] According to the OECD (2023), the number of leniency applications in OECD countries dropped by 58% between 2015 and 2021.

This study employs a laboratory experiment to examine how a multi-jurisdictional leniency program, compared with a single-jurisdictional leniency program, affects leniency applications, considering both its potential positive and negative effects. Specifically, the experiment investigates the impact of these two regimes on the formation, deterrence, and detection of cross-border cartels in supranational markets. The experimental design incorporates two key treatment factors: (1) a comparison between single- and multi-jurisdictional leniency programs under the same expected penalty level, focusing on differences in leniency application procedures—whether firms must apply separately in each jurisdiction (single) or can apply in just one (multi); and (2) a comparison within multi-jurisdictional leniency programs featuring full immunity, partial immunity, or no immunity scenarios, which takes into account institutional discrepancies across competition authorities, where full immunity is not always guaranteed.

The experimental data confirm the deterrent effect of leniency policies on cross-border cartel formation. However, they show that a multi-jurisdictional leniency policy does not necessarily lead to a higher leniency application rate compared with a single-jurisdictional policy. In particular, when full immunity is not guaranteed, a multi-jurisdictional leniency policy reduces leniency applications, lowers cartel detection rates, and increases the number of undetected and surviving cartels. This result highlights the importance of full immunity guarantees for self-reporting cartel firms and regulatory cooperation in implementing multi-jurisdictional leniency policies, providing key policy insights for the adoption of such policies in OECD member states and beyond.

The paper is organized as follows. Section 2 discusses the previous experimental literature on cartel leniency programs. Section 3 describes the experimental design. Section 4 presents hypotheses. Section 5 reports the results, and Section 6 provides a summary of the results and a concluding discussion.

2 Literature review

Numerous prior studies have explored the significance of the design and operation of leniency programs. Motta and Polo (2003) highlight that due to the limited investigative resources of regulatory agencies, leniency programs are effective for obtaining information on cartels and increasing their detection. However, they also warn that leniency programs can reduce the expected costs of collusion, potentially inducing the formation of cartels. Buccirossi and Spagnolo (2006) demonstrate that leniency policies can effectively deter long-term collusive behavior sustained by repeated interactions. However, they caution that poorly designed leniency policies can facilitate temporary illegal transactions, underscoring the importance of proper program design.

Aubert et al. (2006) find that offering rewards for the reporting of illegal activities by cartel firms or their employees increases the likelihood of securing evidence of collusion. This, in turn, raises the cost of collusion as firms strive to prevent employees from reporting evidence, enhancing the deterrent effect more than leniency programs alone. Harrington (2008) analyzes the effectiveness of leniency programs using a model where the probability of detecting and successfully prosecuting collusion changes over time. He shows that leniency programs can destabilize collusion by providing benefits for self-reporting but can also sustain collusion due to the expectation of leniency. Specifically, he finds that granting full immunity to the first reporter is the optimal leniency strategy when the probability of detection is low. Using U.S. data from 1985 to 2005, Miller (2009) empirically demonstrates that leniency programs increase cartel detection rates and deter cartel formation.

Harrington (2013) argues that in scenarios where firms possess more private information about illegal activities than regulatory authorities, leniency programs should provide sufficient incentives to maximize the preemption effect (where firms fear another firm will self-report first) rather than merely increasing the prosecution effect (where firms fear being convicted). Chen and Rey (2013) discuss how leniency programs can help to destabilize cartels but can also have adverse effects. The authors advocate for partial leniency, even after investigations, to encourage firms to break and report cartels. However, the authors stress that leniency programs should grant benefits only to the first reporter to prevent abuse of the program. Lesli et al. (2015) highlight that firms involved in multiproduct collusion decide which items to self-report and which to risk penalties over based on the expected penalties and benefits of leniency for each product market. Therefore, they argue for the design of antitrust leniency policies that take into account the characteristics of multiproduct collusion, linking self-reporting procedures and appropriately allocating investigative resources.

Several experimental studies examine the effects of fine exemptions granted by leniency programs on cartels. The effect of leniency programs on collusion was first examined through an experimental design by Apesteguia et al. (2007). Subsequently, Hinloopen and Soetevent (2008) expanded on the experiment by evaluating the impact of leniency programs on collusion activities and market prices. The experiment involves four treatments: *Benchmark* (base treatment without price discussion), *Communication* (subjects can discuss prices), *Antitrust* (15% random detection of collusion with fines), and *Leniency* (fines reduced through self-reporting). The results indicate that lower prices form only in the *Leniency* treatment, and collusion frequency decreases by about 50% in both *Antitrust* and *Leniency* treatments. This suggests that leniency programs are crucial tools for deterring collusion and stabilizing prices.

Bigoni et al. (2012) examine the impact of fines, leniency programs, and rewards for whistleblowers on the formation of cartels and the stability of collusion and market prices. Their experiment comprises four treatments: *L-Faire* (no fines or leniency), *Fine* (fines imposed for collusion), *Leniency* (full leniency for the first reporter), and *Reward* (additional rewards for whistleblowers). The results show that both *Fine* and *Leniency* reduce cartel formation, lower prices, and increase detection rates, with *Leniency* being more effective. *Reward* also increases detection rates but is less effective than *Leniency* at deterring collusion.

Bigoni et al. (2015) investigate the effects of high fines and full leniency to the first reporter on deterrence of cartel formation. Using a duopoly repeated game, the experiment includes the treatments *Fine* (both parties pay fines upon detection), *Leniency* (100% leniency for the first reporter and 50%

for the second), *L-Faire* (no detection or fines), and *NoReport* (no leniency). The experiment varies the values of the high and low fines and the probability of cartel detection (0%, 2%, 10%) across the treatments. The results show that *Leniency* effectively deters cartel formation, and the size of the fines plays a critical role in deterring collusion, regardless of the detection rate. The findings emphasize that high fines are crucial to the effectiveness of leniency programs in deterring collusion.

Feltovich and Hamaguchi (2018) focus on the direct effect of leniency programs on reducing collusion stability and the counterproductive indirect effect of increasing incentives to form collusion by lowering exit costs. Their experiment consists of three treatments: *No leniency* (no self-reporting or leniency), *Partial Leniency* (partial fine reduction upon self-reporting), and *Full Leniency* (complete exemption from fines). The results show that the introduction of leniency does not increase cartel formation rates, and both *Full Leniency* and *Partial Leniency* reduce market prices and cartel stability. *Full Leniency* leads to higher self-reporting rates than *Partial Leniency* does, indicating that leniency programs contribute to collusion breakdown without significantly promoting cartel formation.

Chowdhury and Wandschneider (2018) investigate the impact of fine size and detection rate on cartel formation, market prices, and cartel stability, with a specific focus on the role of leniency policies. Participants in the study engaged in a repeated Bertrand game, where they decided whether to form a cartel and set prices. The experiment features five treatments: a baseline without a leniency policy, a scenario with low fines and high detection rates, and a scenario with high fines and low detection rates. Each scenario is further divided based on whether a leniency policy is implemented, with all conditions having equal expected costs. The findings reveal that, in the absence of a leniency policy, cartel stability is not significantly influenced by the combination of fines and detection rates. However, when a leniency policy is in effect, cartel members are more likely to apply for leniency under conditions of high fines and low detection rates. This indicates that the size of fines is more crucial than the detection rate in deterring cartels.

Kim and Noussair (2023) examine the impact of fine size and whether leniency applies to one or two reporters on cartel formation, exposure, and success (that is, successfully maintaining collusion without being detected). The experiment includes four leniency treatments (*High1, High2, Low1, Low2*) and a benchmark *No-leniency* treatment. The results indicate that leniency programs do not effectively deter cartel formation but increase cartel exposure and reduce cartel success. Higher fines further reduce cartel success, and partial leniency for subsequent reporters does not significantly affect a program's effectiveness.

Bodnar et al. (2023) examine the impact of private damage claims on collusion and leniency programs. Their experiment adds a private damage claim stage to the traditional collusion and self-reporting framework, comparing *No Private Damage Claims* and *Private Damage Claims*. The results show that private damage claims significantly reduce cartel formation attempts but make existing cartels more stable and reduce self-reporting rates. This indicates that protecting leniency applicants from private damage claims can enhance the incentive to self-report and deter cartel formation due to fears of betrayal by cartel members.

There has been relatively little research on the operation of multi-jurisdictional leniency programs. Choi and Gerlach (2012) were the first to discuss the impact of these programs on the incentives for cartel formation and self-reporting. The authors model the effects of cooperation among antitrust regulatory authorities in different countries on the effectiveness of multi-jurisdictional leniency programs when global cartels operate across multiple jurisdictions. They analyze three scenarios depending on the level of information-sharing among the regulatory authorities in a multi-jurisdictional leniency program. When there is no information-sharing among regulatory authorities, firms' incentives to self-report decrease, making it easier to maintain cartels effectively. When information is shared during investigations, but information obtained through the leniency program is not shared, the increased detection rate from the investigative information-sharing heightens firms' incentives to self-report, reducing cartel formation. However, when regulatory authorities share all information, self-reporting may decrease, depending on fine size and cartel detection rate. This shows that the incentives for self-reporting and the deterrent effect on cartel formation can vary depending on the degree and type of information-sharing.

Luz and Spagnolo (2017) examine how the interaction between leniency programs and whistleblowing programs affects bid-rigging. Although the authors do not directly address multi-jurisdictional leniency programs, they compare antitrust laws and anti-corruption laws applied to the same issue to analyze how leniency programs can reduce the incentives for whistleblowing on corruption cases. They show that the level of cooperation and consistency of enforcement between antitrust and anti-corruption authorities can influence the effectiveness of leniency programs and that double jeopardy and competition between regulatory authorities can undermine the effectiveness of leniency programs. Therefore, the authors suggest that a one-stop shop, where various crimes can be reported simultaneously to receive immunity, could enhance the effectiveness of leniency programs.

Buccirossi et al. (2020) also discuss the conflict between leniency programs and damage claims, a situation that can arise when multiple programs address the same issue, similar to multi-jurisdictional leniency programs. Damage claims can reduce the effectiveness of leniency programs because the evidence provided by leniency applicants can be used by victims, and leniency applicants generally have no incentive to contest violations in court. The authors discuss providing comprehensive immunity, including from civil liability, for leniency applicants and imposing the responsibility on other cartel members to maximize the incentives for self-reporting and increase the fear of betrayal in order to deter cartel formation. Similarly, Caruso (2010) discusses the importance of maintaining the confidentiality of information submitted by leniency applicants under the EU leniency program. The author emphasizes that protecting the confidentiality of information provided by self-reporting firms is essential for the effective operation of leniency programs to prevent those firms from facing disadvantages in civil lawsuits.

Korsten (2022) presents case studies on the impact of multi-jurisdictional leniency programs on cartel deterrence, showing that if leniency applicants are not guaranteed immunity in other jurisdictions, even if they receive immunity in one jurisdiction, their incentives to self-report may decrease, increasing the stability of cartels. Cases where the confidentiality of self-reporting information is not maintained (e.g., in the 2015 Chilean tissue paper cartel involving CMPC Tissue), leniency is recognized only in one jurisdiction (e.g., in the 2010 freight-forwarding cartel involving DHL), or immunity is granted at the EU level but punished by national regulatory authorities (e.g., in the 2011 laundry detergent cartel involving Unilever, Proctor & Gamble, and Colgate Palmolive) are discussed as examples where the effectiveness of leniency programs may be weakened.

In summary, while research on multi-jurisdictional leniency programs is still in its nascent stages, numerous studies underscore the importance of the design and implementation of leniency programs in cartel detection. The findings suggest that cross-national cooperation among regulatory agencies and consistency in the application of leniency policies are vital to encouraging self-reporting and deterring cartels. Previous studies have also shown that private damage claims or whistleblowing programs can diminish the incentives to self-report, and that if leniency is granted in one country but not guaranteed in others, the incentive to self-report can be significantly reduced, leading to increased cartel stability and reduced effectiveness of leniency programs. Therefore, the effective implementation of multi-jurisdictional leniency programs necessitates coordinated efforts among national regulatory agencies to ensure the alignment of reporting processes and leniency applications.

3 Experimental design

3.1 Basic setup

The structure of the experiment is based on that of Choi and Gerlach (2012) and Buccirossi et al. (2020). Every two participants form a group, and each group represents a duopoly market selling a homogeneous product. Each group represents an independent market and its behavior is considered an independent observation. Sessions consist of 15 rounds and the members of each group are fixed until the end of the experiment. The experimental currency accumulates based on decision-making in each round. Then, a last round for payment is randomly determined, and the participant's payoff is calculated as the sum of the accumulated earnings up to that final round and the show-up fee.

Each round consists of two phases. Phase 1 is the *Collusion* stage. In this stage, the participants of each group have 1 minute to communicate with each other via a chat box. All messages from each group are visible only to the members of that group. During the conversation, group members can see the payoff table for their decisions. When the conversation ends, each individual makes a decision about whether or not to collude. In the experiment, this decision is described as a decision whether or not to join the market agreement.[3] In each round, the members of each group make decisions simultaneously. If they both choose "join the market agreement," phase 2 begins; otherwise, the round ends without phase 2.

Phase 2 is the *Leniency* stage. To depict the leniency programs operated by different competition

[3] This procedure is used to simulate the process of cartel formation and subsequent leniency application during a short lab experiment session while ensuring that subjects are not influenced by collusion-related terminology or extraneous prior knowledge when deciding to participate in an incentive-based experimental collusion. See Kim and Noussair (2023).

authorities A and B, there are two opportunities to apply for leniency. In the experiment, making a leniency application is described as "reporting the agreement." If only one of the two members of the group reports the agreement and applies for leniency, the whistleblower is exempt from the fine. However, if both members apply for leniency, only the first applicant is exempt from the fine. If neither applies for leniency, there is an exogenous 15% chance that the formed cartel is discovered and that all members are fined. After the subjects are given two such leniency application opportunities, the net payoffs of the round, which are the sum of the earnings from phase 1 and the fine from phase 2, are revealed to the members and the round ends.

To closely simulate the reality of collusion, the parameters are set based on empirical estimates from previous studies of cartel overcharges and the average fines resulting from competition policy enforcement in various countries. In the experiment, two identical firms 1 and 2 in a market produce a homogeneous good. The inverse demand function is $P = 100 - Q$, where Q is the total output produced in the market, $Q = q_1 + q_2$. Marginal cost for each firm is 40. The cartel maximizes its joint profit, resulting in a quantity of 15 for each firm under collusion. The profit of each firm in the cartel is thus $15 \times (70 - 40) = 450$. A fine is the excess profit between collusion and competition, which is 50, approximately 5% of a cartel member's revenue.[4] Fines may be imposed up to twice depending on decision-making. If both firms

Table 1. Payoffs for Firms 1 and 2 in Phase 1

		Firm 2	
		Join the agreement	**Do not join**
Firm 1	**Join the agreement**	450, 450	337, 506
	Do not join	506, 337	400, 400

* Note: Payoffs are denominated in terms of experimental currency unit, 200 ECU = 1 US dollar. If both firms join a cartel (= join the agreement), then the payoffs are from joint profit maximization. If neither firm joins a cartel, then the payoffs are from Cournot competition. The other two cells represent the payoffs from one firm's deviation.

compete, each firm produces a quantity of 20 with a market price of 60. The Cournot competition payoff for each firm is $20 \times (60 - 40) = 400$.

Table 1 shows the payoffs for each player in phase 1. Table 2 shows the possible fines or reduced fines for a given leniency application in phase 2 and represents the benchmark case: the single-jurisdictional leniency policy. In the single-jurisdictional leniency policy, firms encounter Table 2 twice because the leniency applications to the two antitrust authorities depicted in the experiment do not affect each other. For the treatment representing a multi-jurisdictional leniency policy, I consider that the leniency application for one antitrust authority affects the other, a scenario that is discussed in detail in the next section.

This study employs a randomly chosen last round payment to describe an infinitely repeated game in which participants maximize the discounted sum of their payoffs (Sherstyuk et al., 2013). In the above

[4] In the EU, cartel fines can be up to 10% of a cartel firm's revenue, while in the US, under antitrust laws, fines can be as high as 20% of the market impact, but the actual amount imposed typically equates to about 5% of revenue. In the experiment, the average imposed figure is used to represent cartel fines.

experiment, all groups play 15 rounds and each player's payoff is the sum of their payoffs up to a last round determined by the discount rate of δ.[5] Each round has a probability of 0.1 of being terminated and a probability of 0.9 of moving on to the next round, representing a discount factor of $\delta = 0.9$. For example, the probability of moving from round 1 to round 2 is 0.9, and the probability of moving from round 1 to round 2 to round 3 is $0.9^2 = 0.81$, because the probability of moving from round 2 to round 3 is 0.9, conditional on being in round 2. Similarly, the probability that the payoff total will be determined by round 15 is $0.9^{14} = 0.229$. The probability of going beyond round 15 is $0.9^{15} = 0.206$, so the subjects in this case were paid twice the total payments from rounds 1 through 15 in addition to the participation fee of 10. The discount factor $\delta = 0.9$ is large enough for collusion in the treatments.

3.2 Treatments

The study consists of five treatments, which are shown in Table 3. The benchmark treatment is no leniency (NL). This treatment represents no leniency application opportunities and possible detection by an antitrust authority's investigation. The probability of being detected and fined for collusion is 15%, and the fine is 10% of revenue. The SL treatment represents a single-jurisdictional leniency program, one in which leniency is granted independently by each antitrust authority, leniency applications are made to each

Table 2. Fines for firms in phase 2

		Firm 2	
		Report the agreement	**Do not report**
Firm 1	**Report the agreement**	**(If firm 1 reports first)** 0, 0 with 50% or 0, -50 with 50%	0, 0 with 50% or 0, -50 with 50%
		(If firm 2 reports first) 0, 0 with 50% or -50, 0 with 50%	
	Do not report	0, 0 with 50% or -50, 0 with 50%	0, 0 with 85% or -50, -50 with 15%

* Note: Fines are denominated in ECU. The first leniency applicant is guaranteed to get a full fine exemption, but the second applicant or one who does not report has a 50% chance of being fined. If neither firm reports the agreement, there is a 15% chance that both firms are fined.

antitrust authority, and penalties and exemptions are applied separately. There are two antitrust authorities in the SL treatment, A and B, with separate leniency opportunities and separate penalties and remissions.

The MN, MH, and MF treatments describe a multi-jurisdictional leniency program under which if a cartel firm applies for leniency in more than one country, it may be able to obtain a reduced penalty by sharing information about the collusion across different antitrust authorities. Under MN, information about the collusion is shared with other competition authorities, but there is no penalty reduction for the applicant.

5 See Appendix A.

Under MH, if a colluding firm applies for leniency to antitrust authority A, then A shares the collusion information with another antitrust authority B, and the fine is reduced by half. In the same way, under MF, if the colluding enterprise applies to A for leniency, it is considered the same as if they also applied to B for leniency, and the fine is fully reduced.

In each round, every subject determines its profits by competing or colluding in phase 1. If a cartel is formed in phase 1, a leniency application is made to antitrust authorities A and B in phase 2, and a fine is determined by the leniency application and the detection of collusion by an investigation. Net payoffs for each round are determined by subtracting fines from profits. At the end of each round, information regarding the group's decision, such as whether they formed a cartel, whether they applied for leniency, and the profits and fines incurred in that round, is shared with each subject as common knowledge.

3.3 The sessions

Each treatment had 20 groups, each consisting of 2 members, resulting in a total of 200 subjects. The experiment was programmed in Smartriqs (Molnar, 2019) and conducted via Zoom. It comprised 15 rounds per session, with subjects receiving final payoffs converted at a rate of 1 for every 200 Experimental Currency Units. The subjects were recruited at Seoul National University in South Korea. On average, each session took approximately 50 minutes, and three or four groups participated in each session. Upon entering the scheduled session, subjects received an experiment link, and then were informed about their final

Table 3. Treatments

Treatment	Leniency program	*Investigation coordination*	*Coordination of fine reductions between AAs*
NL	-	-	-
SL	Single-jurisdictional	-	-
MN	Multi-jurisdictional	O	-
MH	Multi-jurisdictional	O	50%
MF	Multi-jurisdictional	O	100%

* Note: *Investigation coordination*, denoted by an "O" in the Multi-jurisdictional leniency program, means that when one antitrust authority (AA) receives an application for leniency, the other AA also initiates an investigation into the case. *Coordination of fine reductions between AAs* involves granting a full or partial reduction of fines to those who apply to the leniency program of another AA.

compensation, consisting of a participation fee of 10 plus additional money based on their decisions during the session. After all participants read the instructions, groups of two were formed and the experiment began.

4 Hypotheses

This section presents the hypotheses tested in the experimental design. The study constructs a theoretical framework and parameters to ensure that cartel formation remains sustainable across all treatments, regardless of the presence or type of leniency program (see Appendix A for details). Since the model is designed to support collusion under all conditions, differences in cartel formation rates across leniency policies cannot be determined theoretically.

This approach is consistent with prior studies, which have examined the effects of leniency under conditions where cartel sustainability remains constant across no-leniency and leniency treatments. These studies have consistently found that leniency programs do not increase cartel formation rates compared with the absence of leniency.[6] Accordingly, following the methodology of previous research, this study formulates hypotheses about cartel formation rates based on the presence or absence of a leniency program, as well as comparisons across different leniency programs, within an environment where collusion remains feasible.

Hypothesis 1a. *The cartel formation rates in the SL, MN, MH, and MF leniency treatments are equal to or lower than that in the NL treatment.*

Hypothesis 1b. *There is no difference in the cartel formation rate between the SL and MF treatment.*

Hypothesis 1c. *There is no difference in the cartel formation rate among the MN, MH, and MF treatments.*

The leniency program treatments describe single-jurisdictional and multi-jurisdictional leniency programs. The differences between these leniency programs are twofold: (1) whether applying to one AA's leniency program influences the initiation of an investigation by the other AA, and (2) whether obtaining a fine exemption under one AA's leniency program entails obtaining a fine reduction or exemption under the other AA's leniency program. These two aspects of the treatments create differences in the expected fines across leniency programs. For clarity, we define the following notation: Let α represent the probability of initiating an investigation and β represent the probability of proving collusion in a given case. Define F as the fine imposed on a cartel firm. Then, the cartel detection rate for cases without a leniency application is $\alpha\beta$.

[6] Previous experimental studies have consistently found that leniency reduces the cartel formation rate, even in environments where collusion is an equilibrium (Apesteguia et al., 2007; Hinloopen and Soetevent, 2008; Bigoni et al., 2012; Bigoni et al., 2015; Clemens and Rau, 2019). The deterrent effect of leniency is particularly strong when fines are high (Chowdhury and Wandschneider, 2018; Kim and Noussair, 2023). Additionally, Feltovich and Hamaguchi (2018) show that leniency does not facilitate cartel formation but instead promotes cartel destabilization. Lesli (2006) further argues that the fear of betrayal among potential whistleblowers serves as a deterrent to cartel formation.

Under SL, when two competition authorities (AAs) operate in the market, each authority conducts cartel investigations, establishes collusion, and imposes fines independently. When a firm applies for leniency to a single authority, an investigation is always initiated, making α=1. In this case, the expected fine imposed by that authority is either 0 or βF, yielding an expected fine of $\frac{1}{2}\beta F$. Therefore, under SL, if a firm applies for leniency to only one authority, the expected total fine across the market is $\left(\frac{1}{2}+\alpha\right)\beta F$, whereas applying to both authorities results in an expected fine of $\left(\frac{1}{2}+\frac{1}{2}\right)\beta F = \beta F$. Under MF, self-reporting to one competition authority is recognized as an application to both, meaning that the fine imposed depends on whether the firm is granted leniency. If the firm receives leniency, the fine is 0; otherwise, the total fine across both jurisdictions is $2\beta F$. As a result, the expected fine under MF is βF. Consequently, the expected fine under SL, $\left(\frac{1}{2}+\alpha\right)\beta F$ or βF is less than or equal to the expected fine under MF (βF) given that $\alpha \leq 0.5$ for sustainable collusion, indicating a lower incentive to make a leniency application in SL. Therefore, one hypothesis regarding leniency application rates is as follows:

Hypothesis 2. *The number of leniency applications in the SL treatment is equal to or lower than that in the MF treatment.*

The third hypothesis is established to compare different multi-jurisdictional leniency programs. In the MN, MH, and MF treatments, when a cartel firm applies for leniency to one AA, the other AA immediately begins an investigation into the matter. However, each treatment represents a leniency program with varying rates of linked leniency reductions for cases where leniency is applied. The fine reductions are 0%, 50%, and 100% for MN, MH, and MF, respectively, resulting in different expected fines for each treatment. As explained in Appendix A, the experimental model is calibrated using parameters from previous research on investigation and cartel detection. Thus, the expected fines are $\frac{3}{2}\beta F$ for MN, $\frac{5}{4}\beta F$ for MH, and βF for MF. As in the comparison between SL and MF, the incentive for leniency application is smaller for MN than for MH, and smaller for MH than for MF. Therefore, I propose the following hypothesis:

Hypothesis 3a. *The number of leniency applications in the MN treatment is lower than that in the MH treatment.*

Hypothesis 3b. *The number of leniency applications in the MH treatment is lower than that in the MF treatment.*

5 Results

5.1 Cartel Formation and Leniency Policy

The experimental data first highlights the likelihood of cartel formation under different leniency policies. In the experiment, collusion is defined in two ways: (1) both players choosing high prices (H), or (2) the two players alternating between high and low prices (H and L, respectively) to avoid the probabilistic fine imposed when both choose H.[7] Table 4 shows the cartel formation rates generated by these two methods. Each treatment consists of 20 groups, and each group plays 15 rounds of the game. Thus, the cartel formation rate is calculated by dividing the number of rounds in which cartels were formed by the total of 300 rounds. Figure 1 illustrates the number of groups that formed cartels in each round, with different colors representing different treatments.

In Table 4, the cartel formation rate is highest in NL (85%), while SL (66%), MN (62%), and MF (61%) produce similar rates of cartel formation, and MH produces the lowest rate. The results of the Mann-Whitney U (MWU) test indicate that all leniency treatments exhibit significantly lower cartel formation rates than the no-leniency treatment in pairwise comparisons (NL vs. SL, $p = 0.054$; NL vs. MF, $p = 0.011$; NL vs. MH, $p < 0.001$; NL vs. MN, $p = 0.047$). This suggests that, regardless of the type of leniency policy, cartel formation rates in a multinational market are lower than in a no-leniency regime. When comparing leniency treatments, MH exhibits a lower cartel formation rate than SL and MN (MH vs. SL, $p = 0.076$; MH vs. MN, $p = 0.063$), while no statistically significant differences are observed in other pairwise comparisons. Figure 1 illustrates the trend in cartel formation rates by round for each treatment. The MWU test results for treatment comparisons are detailed in Appendix A.

Table 4. Cartel formation rate by treatment

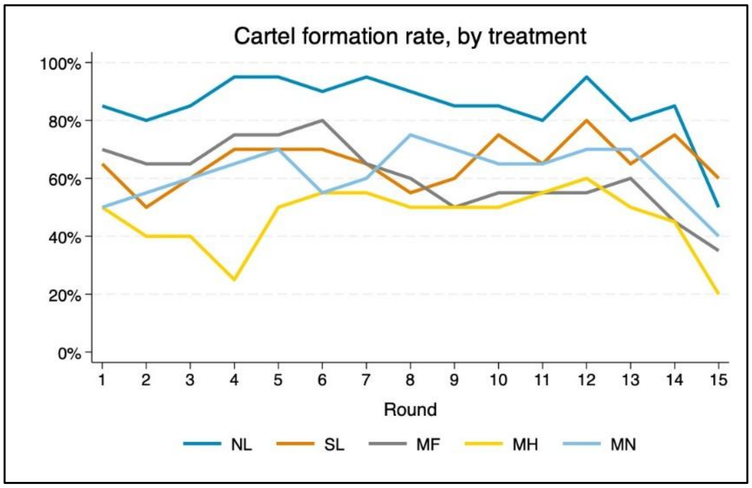
		NL	SL	MF	MH	MN
Cartel formation rate		85%	66%	61%	46%	62%
# of cartels / total periods		255/300	197/300	182/300	139/300	185/300
	By choosing H and H	202	193	182	109	173
	By alternating H and L	53	4	-	30	12

* Cartel formation rate = the number of cartels formed divided by the number of periods (= 15 periods × 20 groups per treatment)

** The number of cartels is the sum of cartels, when the two members choose H and H or alternate between H and L.

7 Gerlach and Li (2024), using the Bertrand model, and Kim (2025), through experiments based on the Cournot model, demonstrate that collusion does not necessarily involve selecting the price or output that maximizes joint profit. Instead, firms may choose alternating prices or outputs to evade regulation. Additionally, Byrne and De Roos (2019) provide empirical evidence of collusion designed to avoid regulation by analyzing the regularity of price change patterns among companies. Therefore, this study confirms through chat interactions during the experiments that such forms of collusion exist and includes them in the count of collusion instances.

Figure 1. Cartel formation rate over 15 rounds



5.2 Self-reporting and the Leniency Application rate

This section compares the frequency of leniency applications. In antitrust law, a cartel leniency application is when cartel members self-report their involvement in exchange for reduced penalties. In the experiment, firms can self-report to antitrust authorities in SL, MF, MH, and MN. In SL, self-reporting can be done to two AAs independently, meaning that reporting to one AA is independent of reporting to the other. In MF, MH, and MN, if a firm whistleblows to one of the two AAs, reporting to the other AA happens automatically. Accordingly, this study defines the leniency application rate as follows: If one or more self-reports occur per round, a leniency application is considered to have occurred in that group (market).

The leniency application rates in Table 5 are calculated, by treatment, as the ratio of the number of periods in which a leniency application occurred to the total number of periods (300 periods).[8] The leniency application rate is highest in SL (38%), followed by MF (27%), then MN (11%), and then MH (8%). However, the results of the MWU test indicate that the difference between SL and MF is not statistically significant ($p = 0.205$). In contrast, both SL and MF exhibit significantly higher leniency application rates than MH and MN (SL vs. MH, $p = 0.003$; SL vs. MN, $p = 0.004$; MF vs. MH, $p = 0.096$; MF vs. MN, $p = 0.074$). No statistically significant difference is observed between MH and MN ($p = 0.371$).

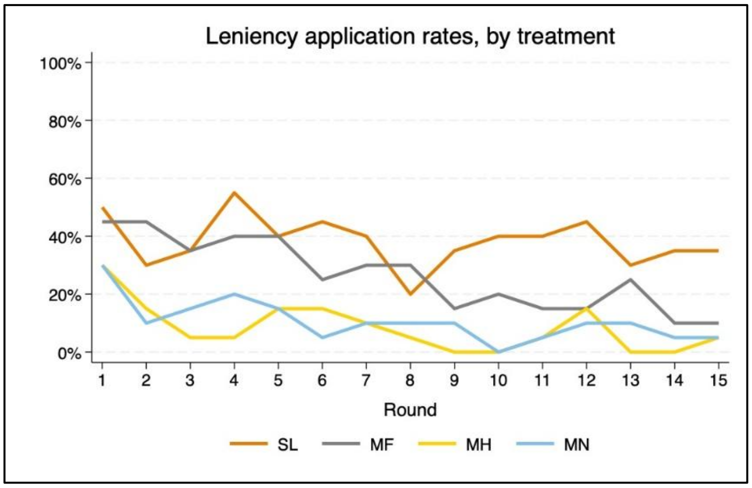
[8] Instead of using the number of periods in which a cartel is formed as the denominator, the total number of periods is used to calculate the leniency application rates. This approach reflects real-world markets, where regulators can observe only the number of firms applying for leniency. Therefore, this measure is employed in the experimental market to align with real-world regulatory observations.

Table 5. Leniency application rate by treatment

	NL	SL	MF	MH	MN
Leniency application rate	-	38%	27%	8%	11%
# of leniency applications / total periods	-	115/300	80/300	25/300	32/300

* If there are one or more self-reports in a period, it is considered that "a leniency application has occurred in that group for that period."
** The leniency application rate = the number of periods in which cartel firms apply for leniency / the total number of periods.

Figure 2. Leniency application rate over 15 rounds



5.3 Cartel Exposure and Cartel Success

This section examines how many of the formed cartels are detected (Cartel Exposure) and how many undetected cartels persist in the market (Cartel Success). First, Table 6 and Figure 3 present the cartel exposure rate, which represents the proportion of formed cartels that are detected. Cartels can be exposed in two ways: (1) through a member of the cartel applying to the cartel leniency program, or (2) through monitoring by antitrust authorities. Thus, the cartel exposure rate is defined as the number of exposed cartels divided by the number of formed cartels.

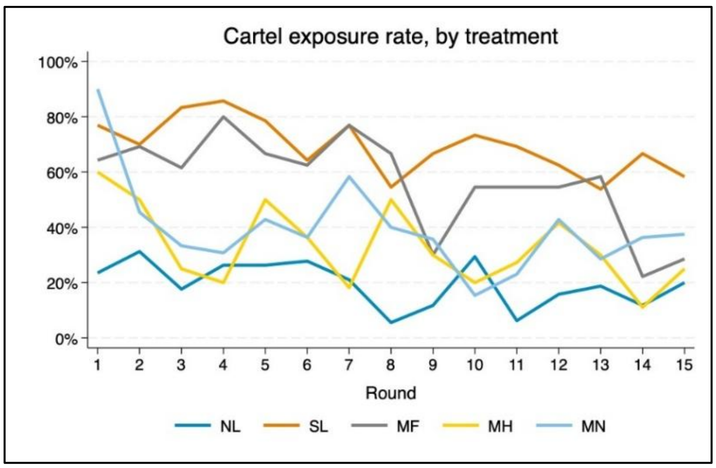
Table 6 shows the cartel exposure rate for each treatment. Comparing no-leniency with leniency treatments, the cartel exposure rate is the lowest in NL (20%), followed by MH (34%), MN (39%), MF (59%), and then SL (70%). The MWU test results indicate statistically significant differences between NL and every leniency treatment; NL vs. SL ($p<0.001$), NL vs. MF ($p<0.001$), NL vs. MH ($p=0.011$), and NL vs. MN ($p=0.003$). When comparing the cartel exposure rates across leniency treatments, there is no statistically significant difference between SL and MF ($p=0.261$), or between MH and MN ($p=0.465$). However, statistically significant differences are observed between SL and MH ($p = 0.027$), SL and MN ($p = 0.008$), MF and MH ($p = 0.085$), and MF and MN ($p = 0.052$).

Table 6. Cartel exposure rate by treatment

		NL	SL	MF	MH	MN
Exposed cartels		**50**	**137**	**108**	**47**	**72**
	By self-reporting	-	115	80	25	32
	By investigation (15%)	50	22	28	22	40
Cartels formed		255	197	182	139	185
Cartel exposure rate*		**20%**	**70%**	**59%**	**34%**	**39%**

* Cartel exposure rate = the number of cartels exposed divided by the number of cartels formed

Figure 3. Cartel exposure rate over 15 rounds



Next, I examine how many cartels remain undetected and persist in the market. The cartel success rate is defined as the number of successful cartels (those that are formed but not exposed) divided by 300 (i.e., 15 rounds × 20 groups per treatment). The cartel success rate is influenced by both the deterrence of cartel formation and the improvement of detection rates. The ultimate goal of antitrust authorities' policies can be described as minimizing the number of these successful cartels.[9]

Table 7 shows the number of successful cartels and the cartel success rate for each treatment. The cartel success rates of leniency treatments are lower than that of the no-leniency treatment. The order, beginning with the lowest success rate, is SL (20%), MF (25%), MH (31%), MN (38%), and NL (68%). The MWU test results show statistically significant differences for NL vs. SL ($p<0.001$), NL vs. MF ($p<0.001$), and NL vs. MN ($p<0.001$), but not for NL vs. MH ($p=0.001$). There are no statistically significant differences in cartel success rates among the leniency treatments.

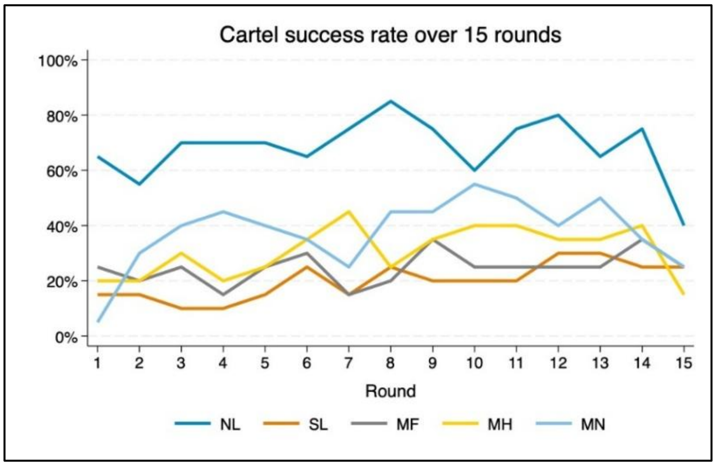
[9] The cartel success rate is unobservable in real-world markets but can be observed in a lab experiment setting. Therefore, this study adopts the cartel success rate measure considered by Kim and Noussair (2023) to examine the extent to which undetected cartels persist under different leniency regimes in multi-national markets.

Table 7. Cartel success rate by treatment

	NL	SL	MF	MH	MN
Successful cartels (= formed but unexposed)	**205**	**60**	**74**	**92**	**113**
Exposed cartels	50	137	108	47	72
Cartels formed	255	197	182	139	185
Cartel success rate*	**68%**	**20%**	**25%**	**31%**	**38%**

* Successful cartels are defined as cartels that are formed and then remain unexposed.
** Cartel success rate = the number of successful cartels divided by 300 (= the total number of periods)

Figure 4. Cartel success rate over 15 rounds



6 Conclusion

This study compares single-jurisdictional leniency policy and multi-jurisdictional leniency policy using a lab experiment. Under a single-jurisdictional policy, opportunities for self-reporting and fine reductions are independent for each antitrust authority. In contrast, under a multi-jurisdictional policy, self-reporting to one AA entails reporting to others. To illustrate how the level of cooperation among AAs can affect the operation of a multi-jurisdictional leniency policy, I categorize the fine reductions offered by the second AA into full, half, and none, and compare these with the single-jurisdictional leniency policy.

I proposed the following hypotheses regarding cartel formation rates and leniency applications: (i) Cartel formation rates do not differ between the absence of a leniency policy and the presence of single-jurisdictional or multi-jurisdictional leniency policies, nor among different types of multi-jurisdictional leniency policies. (Hypotheses 1a, 1b, and 1c); (ii) The number of leniency applications under the single-jurisdictional leniency policy is lesser than or equal to that under the multi-jurisdictional leniency policy with full fine exemption (Hypothesis 2); and (iii) The number of leniency applications decreases along with the level of fine exemption in the multi-jurisdictional leniency policy (Hypotheses 3a and 3b).

The results of the experiment are as follows: (1) All types of leniency policies reduce the number of cross-border cartels more than no leniency; (2) Leniency application rates do not significantly differ between the single-jurisdictional leniency policy and the multi-jurisdictional leniency policy with full fine exemption; (3) Multi-jurisdictional leniency policies without fine exemption yield lower leniency application rates than the single-jurisdictional and full-exemption multi-jurisdictional policies. These results support all hypotheses. Additionally, regarding the improvement of cartel detection rates and the reduction of cartel success rates, the multi-jurisdictional leniency policy guaranteeing full fine exemption does not statistically differ from the single-jurisdictional leniency policy. However, multi-jurisdictional leniency policies without guaranteed full fine exemption are associated with lower detection rates and more successful cartels.

This study's experiment compared cartel formation rates, leniency applications, cartel exposure rates, and cartel success rates under the assumption that regulatory authorities have identical fines, market monitoring power, and probabilities of proving collusion. The comparison shows that when a leniency applicant receives full immunity in one jurisdiction and is guaranteed the same in another, the multi-jurisdictional leniency policy results in no significant differences compared with the single-jurisdictional leniency policy. However, when cartel members who make leniency applications in one jurisdiction are not guaranteed full immunity in another, the multi-jurisdictional leniency policy reduces leniency applications compared with the single-jurisdictional leniency policy, ultimately lowering the cartel exposure rate.

Why does a multi-jurisdictional leniency policy without guaranteed full immunity significantly reduce leniency applications? The findings of this study provide important insights into considerations when transitioning from single-jurisdictional leniency to multi-jurisdictional leniency. When full immunity is not guaranteed, self-reporting to one regulatory authority exposes cartel activities to another authority. This reduces the incentive for cartel members to apply for leniency. Consequently, contrary to the original intention of each regulatory authority to introduce leniency policies to dismantle cartels, the presence of multiple regulatory authorities within the same market structure strengthens the cohesion of cartel members. As a result, cartel members' incentives to apply for leniency decrease, the cartel exposure rate declines, and the number of unexposed cartels increases. This highlights the critical importance of institutional cooperation among regulatory authorities within the same market to guarantee full immunity when operating a multi-jurisdictional leniency policy.

The necessity of introducing a multi-jurisdictional leniency policy is being discussed among various countries, including among OECD members, due to the increasing prevalence of cross-border cartels in transnational markets.[10] A multi-jurisdictional leniency policy has potential for synergy effects, such as

[10] See OECD (2023).

enhanced cooperation in investigations and increased market monitoring capabilities among regulatory authorities.

A limitation of this study is that it does not consider these synergistic effects of regulatory cooperation in its examination of multi-jurisdictional leniency policy. Because the experiment shows that the effect of a multi-jurisdictional leniency policy guaranteeing full immunity across multiple regulatory authorities is similar to that of a single-jurisdictional leniency policy, if the synergistic effects of regulatory cooperation are significant, a multi-jurisdictional leniency policy may indeed be more desirable than a single-jurisdictional leniency policy. This could be an interesting topic for future research.

Despite its limitations, this study demonstrates, through experimental results, the structural importance of coordinated reporting and full immunity when regulatory authorities operate a multi-jurisdictional leniency program. It indicates that when leniency policies are implemented with close cooperation among regulatory authorities, the effective dismantling of cartels, which is the fundamental purpose of these policies, is achievable.

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Appendix

A Expected Payoffs and Conditions for Sustainable Collusion

This section introduces the basic theoretical framework for the experimental design. The basic assumptions when comparing a single-jurisdictional leniency (SL) program with multi-jurisdictional leniency (ML) programs are as follows. Consider a market with two antitrust authorities where two identical firms sell their homogeneous product. Each firm can compete or collude with the other, and in a case where the two firms form a cartel, each can apply for a leniency program. Antitrust authorities (AA) in the experiment are identical and have the same market monitoring power, α, and cartel detection rate due to investigation, β. The definition of the cartel detection rate in several previous studies (Bosch and Eckard Jr, 1991; Combe, Monnier, and Legal, 2008; J. Chen and Harrington Jr, 2007; Miller, 2009) is "the probability of detecting a cartel that exists in a market," which implies $\alpha\beta$ in our study. α is the probability that a market is monitored and investigated by AA when there is suspicion of collusion. β is the probability that an investigated case is proven to be a cartel. There are two strategies that allow collusion to be sustainable in the infinite horizon game: (1) *to collude & conceal*, and (2) *to collude & self-report (i.e., apply for leniency)*. Note that π_C is a firm's cartel profit, π_D is the profit deviating from collusion, π_0 is a firm's profit in a competition, F is the fine imposed on a cartel firm, and δ is the discount rate.

Consider the expected payoff for each strategy. In the *collude & conceal* scenario, firms obtain collusive profits. At this juncture, the expected value of fines, taking into account the probability α of each regulatory authority commencing an investigation and the probability β of detection during such an investigation, is $\alpha\beta F$. Consequently, the expected payoff for the strategy (1) is $\frac{1}{1-\delta}(\pi_C - 2\alpha\beta F)$.[11] In the scenario of *collude & self-report*, the expected payoff may differ under SL and ML programs. The SL program entails independent processing of self-reports to each AA, with investigations initiated separately for each case. Given that there are two AAs in the experimental framework, we can distinguish a colluding firm that reports to only one authority from one that reports to both authorities. In cases where a firm reports to an AA, α is 1 for the AA, indicating a guaranteed investigation, and the fine is either 0 if the report is acknowledged as the first one the AA received, or βF otherwise. The expected fine for a jurisdiction with no report is $\alpha\beta F$. Hence, the expected payoff

[11] In the given scenario, the expected payoff for the single-jurisdictional leniency program is the same as that for the multi-jurisdictional leniency program. This implies that both programs offer the same expected payoff for the '*collude & conceal*' strategy. The probability α mentioned in the scenario represents the likelihood of an investigation occurring. The probability of an investigation occurring in only one of the two places is $2\alpha(1-\alpha)$, and the probability of investigations occurring in both places is $2\alpha^2$. Thus, the expected payoff of the strategy (1) under the multi-jurisdictional leniency program is $\frac{1}{1-\delta}(\pi_C - 2\alpha(1-\alpha)\beta F - 2\alpha^2\beta F) = \frac{1}{1-\delta}(\pi_C - 2\alpha\beta F)$, which is the same as that under the single-jurisdictional leniency program. This structure is useful for providing information about how the operation of leniency programs can impact corporate behavior and for designing effective antitrust policies, especially in the context of multinational corporations operating in a global economy.

for reporting to only one jurisdiction under SL is $\frac{1}{1-\delta}\left(\pi_C-\frac{1}{2}\beta F-\alpha\beta F\right)=\frac{1}{1-\delta}\left(\pi_C-(\frac{1}{2}+\alpha)\beta F\right)$. Following the same rationale, the expected payoff for reporting to both jurisdictions under SL is $\frac{1}{1-\delta}(\pi_C-\beta F)$.

In the SL program, cartel members must apply for leniency from each competition authority separately, whereas in the ML program, an application to one authority is recognized as an application to all. Consequently, in the experimental design, the extent to which fine reductions in one jurisdiction are guaranteed across the other determines the classification into three treatments: MF (full immunity, 100%), MH (half exemption from fines, 50%), and MN (no exemption from fines, 0%). Taking this into account, Table A1 shows the expected fines depending on whether the leniency applicant is the first of its cartel to apply and whether the applicant receives the same exemption status across different AAs. For example, under MN, consider a colluding firm that self-reports to one AA. The fine imposed on the firm by this AA depends on whether it is granted leniency, in which case it faces a fine of either 0 or βF. Additionally, the expected fine from the other AA remains βF. Therefore, under MN, the expected payoff is $\frac{1}{1-\delta}(\pi_C-\frac{3}{2}\beta F)$. Using the same approach, where the expected fines are calculated based on whether the firm is granted leniency or not, the expected payoff for each treatment is as follows: under MN, the expected payoff is $\frac{1}{1-\delta}(\pi_C-\frac{3}{2}\beta F)$; under MH, it is are $\frac{1}{1-\delta}(\pi_C-\frac{5}{4}\beta F)$; and under ML, it is $\frac{1}{1-\delta}(\pi_C-\beta F)$. Collusion is sustainable when the expected payoff for each treatment and strategy, as discussed above, is greater than the payoff in the case of deviation, $\pi_D+\frac{\delta}{1-\delta}\pi_0$. Table A2 presents these conditions.

Table A1: Expected fines following a leniency application to one regulator in MN, MH, and MF treatments

Leniency Application	The probability of being caught by an AA $(1-\beta)^2$	$\beta(1-\beta)$	$(1-\beta)\beta$	β^2	Expected Fine
The first applicant for leniency	$0+0$	$0+0$	MN: $0+F$	$0+F$	βF
			MH: $0+0.5F$	$0+0.5F$	$0.5\beta F$
			MF: $0+0$	$0+0$	0
The second applicant OR Non-applicant	$0+0$	$F+0$	$0+F$	$F+F$	$2\beta F$

* The treatments MN, MH, and MF, which describe multi-jurisdictional leniency programs, produce different expected fines for the leniency applicant depending on the situation. In the MF treatment, the first applicant receives a full exemption from the fine from both the AA to which it applied for an exemption and the AA to which it did not apply, but in the MN and MH treatments, the first leniency applicant receives either no exemption from fines or a 50% reduction in fines if the collusion is detected via an investigation by the AA to which it did not apply for leniency.

This experiment examines cartel formation rates and leniency application rates under different leniency programs. To create an experimental environment conducive to cartel formation and to represent collusion in a manner that closely aligns with real-world conditions, the parameters α, β, δ, and F within the theoretical framework are based on empirical estimates derived from previous research. Thus, the expected payoff of strategy (1) must exceed that of strategy (2) in Table A2. When $\alpha \leq 0.5$, this condition holds across all leniency treatments. This condition is intuitively understandable, as choosing to make a leniency application is preferable to concealing membership in a cartel if the AAs' market monitoring power is sufficiently high, and vice versa for low market monitoring power.

In practice, α and β cannot be independently identified. Instead, prior studies have estimated cartel detection rates (=$\alpha\beta$) as follows. Bosch and Eckard Jr. (1991) estimated $\alpha\beta$ as falling between 0.13 and 0.17 while Combe et al. (2008) estimated it falling between 0.129 and 0.133. Furthermore, Miller (2009) showed that the implementation of a leniency program for whistleblowers increases the cartel detection rate to between 46% and 55%. Thus, this experimental study adopts these results, applying $\alpha\beta = 0.15$ and $\beta = 0.5$, which implies that $\alpha = 0.3$, making the *collude & conceal* strategy the dominant one. The required $\delta \geq \delta^*$ for collusion is 0.76 for MF, 0.82 for MH, and 0.88 for MN, and therefore 0.9 is set as δ in the experiment. F applies the average amount of the fine imposed at the time of the cartel (about 5% of revenue).

Table A2: Conditions for Collusion Sustainability by Treatment

	Strategy (1) *Collude & Conceal*	Strategy (2) *Collude & Self-report*
NL		-
SL		① $\frac{1}{1-\delta}\left(\pi_C - \left(\frac{1}{2}+\alpha\right)\beta F\right) \geq \pi_D + \frac{\delta}{1-\delta}\pi_0$ ② $\frac{1}{1-\delta}(\pi_C - \beta F) \geq \pi_D + \frac{\delta}{1-\delta}\pi_0$
MF	$\frac{1}{1-\delta}(\pi_C - 2\alpha\beta F) \geq \pi_D + \frac{\delta}{1-\delta}\pi_0$	$\frac{1}{1-\delta}(\pi_C - \beta F) \geq \pi_D + \frac{\delta}{1-\delta}\pi_0$
MH		$\frac{1}{1-\delta}(\pi_C - \frac{5}{4}\beta F) \geq \pi_D + \frac{\delta}{1-\delta}\pi_0$
MN		$\frac{1}{1-\delta}(\pi_C - \frac{3}{2}\beta F) \geq \pi_D + \frac{\delta}{1-\delta}\pi_0$

* In the SL treatment, the expected payoffs for the strategy *Collude & Self-report* vary depending on the number of antitrust authorities to which a firm applies for leniency. The inequality ① indicates a condition when a firm applies for leniency from only one authority, and the inequality ② represents the condition when a firm applies for leniency from both authorities.

B Mann-Whitney (MWU) test results

This section includes the results of the Mann-Whitney U (MWU) test to compare the cartel formation rate, leniency application rate, cartel exposure rate, and cartel success rate by treatment. For the comparisons among treatments, one observation refers to the above-four rates for a group over 15 rounds, which means 20 observations per treatment are used in the MWU test. The cells in the table below represent the p-values from the MWU test results for comparisons between the treatments indicated by the rows and columns. According to the hypotheses in Section 4, one-sided p-values from MWU tests are used to compare one-directional differences between the NL treatment and the leniency treatments (SL, MF, MH, and MN). Additionally, comparisons among multi-jurisdictional leniency treatments (MF, MH, and MN) also use one-sided p-values. Comparisons between single-jurisdictional leniency (SL) and each of multi-jurisdictional leniency treatments (MF, MH, and MN), which do not have directional hypotheses, use two-sided MWU test results. Table A3 shows the differences in cartel formation rate and leniency application rate by treatment, and Table A4 presents the differences in cartel exposure rate and cartel success rate.

Table A3: MW test results for treatment differences in cartel formation rate / leniency application rate

(a) Cartel formation rate

	SL	MF	MH	MN
NL	**0.054**	**0.011**	**0.000**	**0.047**
SL	-	0.530	**0.076**	0.815
MF		-	0.117	0.381
MH			-	**0.063**

(b) Leniency application rate

	SL	MF	MH	MN
NL	-	-	-	-
SL	-	0.205	**0.003**	**0.004**
MF		-	**0.096**	**0.074**
MH			-	0.371

Table A4: MW test results for treatment differences in cartel exposure rate / cartel success rate

(a) Cartel exposure rate

	SL	MF	MH	MN
NL	**<0.001**	**<0.001**	**0.011**	**0.003**
SL	-	0.261	**0.027**	**0.008**
MF		-	**0.085**	**0.052**
MH			-	0.465

(b) Cartel success rate

	SL	MF	MH	MN
NL	**<0.001**	**<0.001**	**<0.001**	**0.001**
SL	-	0.716	0.545	0.121
MF		-	0.378	0.122
MH			-	0.210

C Instructions (MF treatment)

General instructions[12]

This is an experiment in economic decision making. The instructions are simple, and if you follow them carefully and make good decisions, you can earn a considerable amount of money. In this experiment, your earnings will be determined by your choices, another participant's choices, and chance. The currency used in the experiment is ECU, Experimental Currency Units. The ECU that you have at the end of the experiment will be converted to dollars at a rate of 200 ECU to 1 dollar and paid to you as a bonus. In addition, you receive a show-up fee for completing the experiment. From now until the end of the experiment, you may not communicate with any other participants outside the chatroom that we will organize.

In the experiment, you will be paired with another participant in a group of two people. You will remain paired with the same person for the entire experiment. Each of you plays the role of a company in the same two-company market. The experiment consists of 15 rounds in total, and the companies in your market will stay the same over the 15 rounds. During the experiment, you will not know what person is playing the other company. The person playing the other company will also be unable to gain this information about you.

Each round consists of two phases. In the first phase of each round, each company in the market can communicate with the other using a chat window. Afterward, each company announces whether it wishes to participate in a market agreement with the other company. In the second phase, each company that entered into the agreement may choose to report the agreement to a market monitor.

Your earnings will depend on whether or not you choose to join the market agreement. Your earnings will also depend on whether or not you or the other company report the agreement. Each round will proceed in the following manner.

Phase 1

In the first phase of each round, a chat window will appear for 60 seconds. You can communicate with the other company in your market by typing in the chat window. Your own text and that of the other participant in your group will always be available for both of you to view. It cannot be seen by any members of other groups. You can see how much time remains in the chat by looking at the top of your chat window. After 60 seconds, the chat window will close.

[12] In the experiment, the term "cartel" was replaced with the neutral term "market agreement" to prevent the negative connotations of the original term from influencing the experimental results.

After the chat ends, a new screen will appear where you must select whether or not you would like to join a market agreement, Join (J) or Not (N). If both companies choose to join, then an agreement is made. Your earnings at this point depend on whether or not an agreement is formed.

∗ If both companies join the agreement, each company receives 450 ECU.

∗ If you join the agreement but the other does not, you receive 337 ECU, while the other gets 506 ECU.

∗ If you do not join the agreement but the other does, you receive 506 ECU while the other gets 337 ECU.

∗ If neither company joins the market agreement, then each receives 400 ECU.

The other / You	Join the agreement	Do not join
Join the agreement	450, 450	337, 506
Do not join	506, 337	400, 400

Phase 2

If both companies choose to join, the market agreement is made and both companies move on to phase 2. Only those who have entered the agreement take part in phase 2. In phase 2, each company that joined the agreement can select whether or not to report the agreement to a market monitor. There are up to two opportunities to report the agreement, Opportunity A and Opportunity B.

- Opportunity A

∗ If you choose to report the agreement and you are the first to report, then you do not lose any earnings.

∗ If you opt to report the agreement but are the second to do so, there is a 25% chance that you will not incur any losses, a 50% chance that you will lose 50 ECU, and a 25% chance that you will lose 100 ECU.

∗ If you choose not to report the agreement, but the other chooses to report the agreement, there is a 25% chance that you will not incur any losses, a 50% chance that you will lose 50 ECU, and a 25% chance that you will lose 100 ECU.

∗ If neither company in the agreement reports, there is a 15% chance that the agreement is discovered by a market monitor anyway, and each company loses 50 ECU. Otherwise, no companies lose any earnings.

See the table of possible losses below.

<table>
<tr><td>The other
You</td><td colspan="2">Report the agreement</td><td>Do not report</td></tr>
<tr><td rowspan="2">Report the agreement</td><td>(If 1 reports as the first)</td><td>0,0 with 25%
OR
0, -50 with 50%
OR
0, -100 with 25%</td><td rowspan="2">0,0 with 25%
OR
0, -50 with 50%
OR
0, -100 with 25%</td></tr>
<tr><td>(If 2 reports as the first)</td><td>0,0 with 25%
OR
-50, 0 with 50%
OR
-100, 0 with 25%</td></tr>
<tr><td>Do not report</td><td colspan="2">0,0 with 25%
OR
-50, 0 with 50%
OR
-100, 0 with 25%</td><td>0,0 with 85%
OR
-50, -50 with 15%</td></tr>
</table>

In addition, if either you or the other participant reports the agreement at Opportunity A, then Opportunity B is not given and the round is complete.

- Opportunity B

If neither you nor the other participant report the agreement at Opportunity A, you both have the option to report during Opportunity B. See the table of possible losses below.

<table>
<tr><td>The other
You</td><td colspan="2">Report the agreement</td><td>Do not report</td></tr>
<tr><td rowspan="2">Report the agreement</td><td>(If 1 reports as the first)</td><td>0,0 with 25%
OR
0, -50 with 50%
OR
0, -100 with 25%</td><td rowspan="2">0,0 with 25%
OR
0, -50 with 50%
OR
0, -100 with 25%</td></tr>
<tr><td>(If 2 reports as the first)</td><td>0,0 with 25%
OR
-50, 0 with 50%
OR
-100, 0 with 25%</td></tr>
<tr><td>Do not report</td><td colspan="2">0,0 with 25%
OR
-50, 0 with 50%
OR
-100, 0 with 25%</td><td>0,0 with 85%
OR
-50, -50 with 15%</td></tr>
</table>

∗ If you choose to report the agreement and you are the first to report, then you do not lose any earnings.
∗ If you opt to report the agreement but are the second to do so, there is a 25% chance that you will not incur any losses, a 50% chance that you will lose 50 ECU, and a 25% chance that you will lose 100 ECU.
∗ If you choose not to report the agreement, but the other chooses to report the agreement, there is a 25% chance that you will not incur any losses, a 50% chance that you will lose 50 ECU, and a 25% chance that you will lose 100 ECU.
∗ If neither company in the agreement reports, there is a 15% chance that the agreement is discovered by a market monitor anyway, and each company loses 50 ECU. Otherwise, no companies lose any earnings.

Since Opportunities A and B are independent of each other, each company may lose 0 or 50 or up to 100 ECU, depending on whether each company reports the agreement or not and on whether a market monitor discovers the agreement.

How to calculate your earnings for each round

Your earnings will be determined by the choices you and the other participant make in phase 1 of a round, and if both of you join the agreement, in phase 2 of that round. Your possible losses depend on whether or not you choose to report the agreement. If either or both of you do not join the agreement, there is no phase 2 for that round. You will be notified of your earnings and those of the other participant at the end of the round.

How many rounds count toward your 'final earnings'

In this experiment, you will play 15 rounds, but some of them might not count toward what you earn. Imagine this: after each round, a 10-sided die is rolled. If a 1 is rolled, then the round you just finished is the last one that will add to your earnings. If any number from 2 to 10 is rolled, you get to count the next round in your earnings too. This means that independently, each round has a 90% chance of contributing to your earnings. Because each round may be your last, round 1 always counts, round 2 has a 90% chance of counting, round 3 has about an 81% chance of counting, and so on. The catch is, you won't see these rolls of the die, and you won't know which round was your last one to count until the experiment is over. There is also a possible bonus. If the die never lands on 1 during any of the 15 rounds, then you'll receive double the earnings from those 15 rounds. There's a 20% chance that this could happen.

Now, click "Next" to wait for the other player and get the game started!

D Payoff tables for the treatments

The following payoff and fine tables represent those used for each treatment in the experiment. Figure A1 is used in Phase 1 of all treatments and shows the payoffs based on whether an individual firm participates in collusion or not. For example, if both companies participate in collusion, each receives a payoff of 450. If one company decides to participate in collusion and the other does not, the non-participating or deviating company gets 506, while the other gets 337. If neither participates in collusion, they each get 400. Figures A2 through A5 depict the fine tables for each treatment, showing the fines each company faces based on whether each collusion participant applies for leniency and the detection rate of collusion investigations, $\beta(= 0.5)$. If neither company applies for leniency, $\alpha\beta(= 0.3 \times 0.5 = 0.15)$ is applied as the collusion detection rate. In cases where collusion is detected, a regulatory agency's fine is 50.

1 \ 2	**Join the agreement**	**Do not join**
Join the agreement	**450, 450**	**337, 506**
Do not join	**506, 337**	**400, 400**

Figure A1: The payoff table for all treatments

<table>
<tr><th>1 \ 2</th><th colspan="2">Report the agreement</th><th>Do not report</th></tr>
<tr><td rowspan="2">Report the agreement</td><td>(If 1 reports as the first)</td><td>0,0 with 50%
OR
0, -50 with 50%</td><td rowspan="2">0,0 with 50%
OR
0, -50 with 50%</td></tr>
<tr><td>(If 2 reports as the first)</td><td>0,0 with 50%
OR
-50, 0 with 50%</td></tr>
<tr><td>Do not report</td><td colspan="2">0,0 with 50%
OR
-50, 0 with 50%</td><td>0,0 with 85%
OR
-50, -50 with 15%</td></tr>
</table>

Figure A2: The fine table for the SL treatment

2 1	Report the agreement		Do not report
Report the agreement	(If 1 reports as the first)	0,0 with 25% OR 0, -50 with 25% OR -50, -50 with 25% OR -50, -100 with 25%	0,0 with 25% OR 0, -50 with 25% OR -50, -50 with 25% OR -50, -100 with 25%
	(If 2 reports as the first)	0,0 with 25% OR -50, 0 with 25% OR -50, -50 with 25% OR -100, -50 with 25%	
Do not report	0,0 with 25% OR -50, 0 with 25% OR -50, -50 with 25% OR -100, -50 with 25%		0,0 with 85% OR -50, -50 with 15%

Figure A3: The fine table for the MN treatment

2 1	Report the agreement		Do not report
Report the agreement	(If 1 reports as the first)	0,0 with 25% OR 0, -50 with 25% OR -25, -50 with 25% OR -50, -100 with 25%	0,0 with 25% OR 0, -50 with 25% OR -25, -50 with 25% OR -25, -100 with 25%
	(If 2 reports as the first)	0,0 with 25% OR -50, 0 with 25% OR -50, -25 with 25% OR -100, -25 with 25%	
Do not report	0,0 with 25% OR -50, 0 with 25% OR -50, -25 with 25% OR -100, -25 with 25%		0,0 with 85% OR -50, -50 with 15%

Figure A4: The fine table for the MH treatment

2 1	Report the agreement		Do not report
Report the agreement	(If 1 reports as the first)	0,0 with 25% OR 0, -50 with 50% OR 0, -100 with 25%	0,0 with 25% OR 0, -50 with 50% OR 0, -100 with 25%
	(If 2 reports as the first)	0,0 with 25% OR -50, 0 with 50% OR -100, 0 with 25%	
Do not report	0,0 with 25% OR -50, 0 with 50% OR -100, 0 with 25%		0,0 with 85% OR -50, -50 with 15%

Figure A5: The fine table for the MF treatment