Antitrust Leniency with Multi-Product Colluders*

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Abstract

We model alternative implementations of an antitrust leniency program as applied to multi-product colluders. Our model involves a game of incomplete information, where the results of the global games literature implies that the risk dominant equilibrium prevails. We show that linking leniency across products can reduce detection and deterrence, giving firms an incentive to create sacrificial cartels in minor products in order to protect more valuable ones. Our results offer a variety of lessons for the design of leniency programs.

Keywords: Amnesty Plus, Cooperation Policy, Cartels, Collusion, Leniency Program, Multimarket Contact
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1 Introduction

In recent years, antitrust leniency programs in the United States, European Commission, Australia, and elsewhere have played an important role in allowing competition authorities to successfully prosecute major price fixing conspiracies.[1] While acting as Director of Criminal Enforcement of the Antitrust Division at the U.S. Department of Justice, Scott D. Hammond stated in a 2001 speech:

> Over the last five years, the Amnesty Program has been responsible for detecting and prosecuting more antitrust violations than all of our search warrants, consensual-monitored audio or video tapes, and cooperating informants combined. It is, unquestionably, the single greatest investigative tool available to anti-cartel enforcers. Since we expanded our Amnesty Program in 1993, there has been more than a ten-fold increase in amnesty applications. In the last two years, cooperation from amnesty applicants has resulted in scores of convictions and well over $1 billion in fines. Moreover, a number of other countries, including Canada, the United Kingdom, Germany, and Brazil, as well as the European Union (EU), have followed with their own leniency programs.[2]

A review of the European Commission (EC) decisions in cartel cases for 2001–2012 shows that of the 101 products in which firms were prosecuted,[3] in 55 (54%) of those products a firm received a 100% reduction in the fine through the leniency program. The EC's leniency program also offers smaller fine reductions for cooperators other

[1] "The Antitrust Division's Leniency Program is its most important investigative tool for detecting cartel activity. Corporations and individuals who report their cartel activity and cooperate in the Division's investigation of the cartel reported can avoid criminal conviction, fines, and prison sentences if they meet the requirements of the program." (United States Department of Justice website, http://www.justice.gov/atr/public/criminal/leniency.html, accessed October 22, 2012)

As Chairman of the ACCC, Graeme Samuel stated that ACCC's Immunity Policy for Cartel Conduct was "absolutely vital" in the Australian governmnet's efforts to crack cartels and credited it with exposing potential cases at the rate of about one a month.

[2] "When Calculating the Costs and Benefits of Applying for Corporate Amnesty, How Do You Put a Price Tag on an Individual's Freedom?," presented at the ABA's Criminal Justice Section's Fifteenth Annual National Institute on White Collar Crime, March 8, 2001, available at http://www.justice.gov/atr/public/speeches/7647.pdf (accessed October 30, 2012).

[3] Some EC decisions apply to more than one product. For example, the EC decision in Vitamins covers multiple vitamin products, with a separate application of the leniency program for each product.

than the first to apply for leniency. In 87 (86%) of the products, a firm received some reduction in the fine through the leniency program.[4]

Table 1: EC cartel cases 2001–2012 with a firm receiving a 100% fine reduction based on the leniency program

Cases in which a firm received a 100% fine reduction		
Airfreight	Elevators and escalators	Methylglucamine
Aluminium Fluoride	Exotic fruit (bananas)	Monochloroacetic Acid
Animal Feed Phosphates	Fine art Auction Houses	Mountings for windows and window-doors
Bananas	Fittings	Needles
Bathroom fittings & fixtures	Food flavour enhancers	Netherlands beer market
Bitumen Nederland	Freight forwarding	Organic peroxide
Bitumen Spain	Gas insulated switchgear	Power transformers
Calcium carbide	Hard haberdashery: fasteners	Prestressing steel
Candle waxes	Heat stabilisers	Refrigeration compressors
Carbonless paper	Hydrogen peroxide	Rubber chemicals
Chloroprene rubber	Industrial bags	Sodium Chlorate
Choline chloride	LCD	Sorbates
Consumer Detergents	Luxembourg brewing industry	Specialty graphite
Copper plumbing tubes	Marine hoses	Synthetic rubber (BR/ESBR)
CRT glass bulbs	Methacrylates	Vitamins
DRAM	Methionine	Water management products
Electrical and mechanical carbon and graphite products		

As suggested in Hammond's comments above, antitrust leniency programs can take different forms.[5] One of the key changes to the U.S. antitrust leniency program in 1993 was to allow firms to apply for leniency even after the Department of Justice had received information about illegal antitrust activity (so-called Type B leniency).[6] Changes to the EU antitrust leniency program in 2002 also allowed for leniency after an investigation had been opened.[7] Additional changes to the U.S. antitrust leniency program include the Amnesty Plus program implemented in 1999 in response to concerns about offending firms being involved in price fixing conspiracies in multiple

[4] In the United States, an official at the U.S. Department of Justice has stated that, in addition to the intial leniency applicant, as many as four firms may receive a "substantial assistance" discount on their fine of as much as 25–30%. (Statements of Lisa Phelan, head of the National Criminal Enforcement Section, at the 61st ABA Antitrust Law Spring Meeting, April 10–12, 2013, as reported by MLex, "Up to Four Companies Can Be 'Second-In' To Get Antitrust Cooperation Discount, Official Says," April 10, 2013.

In Australia, only one firm can obtain a discount under the Immunity Policy for Cartel Conduct, but others may obtain a discount under the Cooperation Policy.

[5] For a description of the evolution of U.S. and EC leniency programs, see Wils (2008, Chapter 5).

[6] According to Motta and Polo (2003, p.349), "The key mechanism of leniency programs is the rule that allows firms to receive fine reductions even after an investigation is opened."

In Australia, leniency applications are permitted until the ACCC has received written legal advice that it has sufficient evidence to commence proceedings in the case.

[7] See Spagnolo (2008, Section 7.2.2) and Stephan (2008, p.554 and Table 4).

product markets.[8] Under Amnesty Plus, a firm being prosecuted for collusion that has not received leniency can potential qualify for reduced fines if it applies for leniency in a separate product in which it is also engaged in collusion. Under the U.S. Penalty Plus program, the failure to report collusion in separate products can put firms at risk for increased penalties should they later be prosecuted for collusion in those products.[9] In addition, other policy changes have occurred related to the treatment of ringleaders, the scope for individual leniency and "carve outs" that can exclude certain individuals from being covered under corporate leniency,[10] and the priorities of competition authorities in settlement negotiation.

Just as policies related to antitrust leniency have evolved, undoubtedly so have cartel strategies for dealing with leniency. Cartels have now had 20 years of experience with leniency in the United States in roughly its current form. This raises questions about cartel strategies to undermine or even benefit from leniency policies. As stated by Wils (2008):

> [S]uccessful cartels tend to be sophisticated organisations, capable of learning. It is thus safe to assume that cartel participants will try to adapt their organisation to leniency policies, not only so as to minimise the destabilising effect, but also, where possible, to exploit leniency policies to facilitate the creation and maintenance of cartels. This raises the question whether

[8]See Lefouili and Roux (2012) for a discussion and theoretical model of Amnesty Plus. See also Wils (2008, Chapter 5.4.4).

[9]Masoudi (2007, p.8) describes the Penalty Plus program as follows: "If a company participated in a second antitrust offense and does not report it, and the conduct is later discovered and successfully prosecuted, where appropriate, the Antitrust Division will urge the sentencing court to consider the company's and any culpable executives' failure to report the conduct voluntarily as an aggravating sentencing factor. We will pursue a fine or jail sentence at or above the upper end of the Sentencing Guidelines range. Moreover, where multiple convictions occur, a company's or individual's sentencing calculations may be increased based on the prior criminal history."

[10]The DoJ may "carve out" individuals from the protection of corporate leniency, including, historically, "culpable employees, employees who refuse to cooperate with the Division's investigation, and employees against whom the Division is still developing evidence." (Scott D. Hammond, Deputy Assistant Attorney General for Criminal Enforcement, Antitrust Division, U.S. Department of Justice, "Charting New Waters in International Cartel Prosecutions," March 2, 2006, available at http://www.usdoj.gov/atr/public/speeches/214861.htm) However, recently, the DoJ has indicated that it will no longer carve out employees stated that it "will no longer carve out employees for reasons unrelated to culpability," which presumably includes a refusal to cooperate. (Bill Baer, Assistant Attorney General Press Release, Antitrust Division, U.S. Department of Justice, "Changes to Antitrust Division's Carve-Out Practice Regarding Corporate Plea Agreements," April 12, 2013, available at http://www.justice.gov/opa/pr/2013/April/13-at-422.html)

there could be features of leniency programmes that risk being exploited to perverse effects. (Wils, 2008, p.137)

In this paper we focus on the effect of leniency policies on multi-product colluders and, in particular, consider whether leniency policies actually enhance incentives for multi-product collusion, potentially through the creation of a sacrificial cartel that offers protection from leniency applications for cartels in other more valuable markets.

The list of firms engaged in collusion in more than one product is long. Table 2, which is based on EC cartel cases, lists multi-product colluders that have received a 100% fine reduction through the leniency program in at least one of the products in which they were prosecuted.

Table 2: Multi-product colluders that received a complete fine reduction in at least one product in EC cartel cases 2001–2012

Firm	Number of products	No fine reduction	Incomplete fine reduction	Complete fine reduction
Akzo Nobel	9	2	4	3
Takeda	6	4	1	1
Aventis	5		2	3
William Prym	5	1	3	1
Bayer	4		2	2
KONE	4	1	1	2
Otis	4		3	1
Degussa	3		1	2
Merck	3	1	1	1
Samsung	3		1	2
Shell	3	2		1
ABB Ltd	2	1		1
Boliden	2		1	1
BP	2			2
Chemtura	2			2
Chiquita	2			2
DHL and Exel	2			2
GrafTech International	2			2
Kemira Oyj	2	1		1
Mueller	2			2
Siemens	2	1		1

Table 3 shows firms colluding in three or more products that did not receive a complete fine reduction in any of the products where they were prosecuted. There were an additional 38 multi-product colluders that were colluding in only two products and that did not receive a complete fine reduction in either.

Table 3: Multi-product colluders that colluded in three or more products and that did not receive a complete fine reduction in any product in EC cartel cases 2001–2012

Firm	Number of products	No fine reduction	Incomplete fine reduction	Complete fine reduction
Roche	13	4	9	
BASF	11	2	9	
Arkema	6	3	3	
Coats	6	3	3	
Elf Acquitaine	4	1	3	
Schindler	4	3	1	
SGL	4		4	
ThyssenKrupp	4	2	2	
AC Treuhand	3	3		
Barbour Threads	3	1	2	
Hitachi	3	3		
Schenker	3	1	2	
Toshiba	3	3		
UPS	3	3		
YKK	3	1	2	

In this paper, we construct a model that allows us to examine the effects on multi-product colluders of different implementations of an antitrust leniency program by a competition authority. Our model was developed using information obtained in detailed interviews with defense attorneys experienced in taking firms through the leniency process at the U.S. Department of Justice (DoJ). Based on these interviews, corporate leniency applications occur under three general sets of circumstances: applications under Type A leniency, which means the DoJ has not yet opened an investigation; applications under Type B leniency, which means the DoJ has already opened an investigation; and follow-up leniency applications under the Amnesty Plus program, where the firm is being prosecuted for collusion in one product and applies for amnesty in a separate product. Based on interviews with defense attorneys, the division between Type A and Type B leniency is approximately 80-90% Type B and 10-20% Type A.[11] In the model, we focus on type B leniency and follow-up leniency

[11] In the United States, the Department of Justice maintains the confidentiality of leniency applicants, although in some cases the identity of a leniency applicant is available through other sources. European Commission decisions in cartel cases identify leniency applicants. A review of these cases shows that the percentage of cases in which a firm applies for leniency prior to the start of an investigation by the EC is greater than the 10-20% indicated for the United States. However, in many of these cases, it may be that the firm was applying for leniency in Europe as a response to an investigation in the United States. According to Bloom (2007), roughly half of the leniency applications received by the EC follow leniency applications in the United States: "One important factor that is likely to lead to an overestimate of the success of the EC leniency program is where applications to the Commission either followed on from those to the US Department of Justice (DOJ) or were simultaneous. The prime aim of any applicant is normally to avoid US criminal sanctions. But once a US investigation is stimulated by an amnesty application, other authorities will start

applications, but we describe all three types below.

It is also possible in the U.S. for an individual leniency applicant to preempt any corporate leniency applicants. This circumstance is fairly rare, but as we discuss later can be viewed as increasing the probability that colluding firms are successfully prosecuted in the absence of a corporate leniency applicant.

An application for type A leniency would unfold as follows: The involvement of the firm in potentially illegal activity comes to the attention of an employee. Perhaps the employee observes documents or overhears conversations indicating collusion, or perhaps the employee recently received antitrust compliance training and so now recognizes certain activities by the firm's employees as potentially of concern. The employee reports the concerns to the firm's general counsel. The general counsel decides whether to bring in outside counsel to investigate. If brought in, the outside counsel would investigate and report to the firm's board of directors. If outside counsel finds evidence of illegal activity, the board will likely feel compelled to address that activity within the firm and will need to make a decision regarding leniency. The board will weigh the tradeoffs between applying for leniency and not, considering the probability that the activity goes undetected for five years, in which case the statute of limitations would end the firm's legal liability. In this scenario, it would be unusual for there to be a race among the colluding firms to apply for leniency since the scenario is driven by events within a single firm.[12]

An application for type B leniency would unfold as follows: Potential collusion in a product comes to the attention of the DoJ, perhaps because buyers of the product or their trade association have approached the DoJ with economic circumstantial evidence suggestive of collusion.[13] The DoJ opens an investigation. When the colluding

investigations as they become aware at some stage of the US one. Hence applications need to be made simultaneously to other authorities or as soon as possible after one to the DOJ. It is the US powers rather than the EC (or other jurisdiction) powers which drive these applications. However, if the applicants could not secure leniency in the EC as well as the US it is highly likely that a significant proportion of them would not apply for US amnesty as they would not be able to avoid heavy EC fines. In approaching half of the EC cases from 2000 there was a prior or simultaneous application for amnesty under the US program." (Bloom, 2007, pp.8–9)

[12]There are exceptions, for example if the triggering event was something that was observed by employees in multiple conspiring firms.

[13]As stated in Wils (2008, pp.127–128), aside from obtaining information from colluding firms themselves, competition authorities could "monitor markets, observing publicly available information and data, and possibly use economic analysis of these data to try to detect and prove violations" or "customers or competitors harmed by antitrust violations may bring complaints to the authorities, and third parties may otherwise volunteer to provide information." See Kovacic, Marshall,

firms become aware of the investigation, they contact their outside legal counsel. It is natural to expect firms to become aware of an investigation at approximately the same time because public information would be available to all and subpoenas would typically be served on the same day. Outside counsel contacts the DoJ to find out whether leniency is still available. If it is, counsel starts an internal investigation at the firm to assess whether the firm has been engaged in illegal activity, in particular whether there is sufficient evidence to enable the firm to admit definitively to a violation of the antitrust laws. Counsel reports the results of the investigation to the firm's board of directors. If there is evidence of illegal activity, outside counsel will report this to the board and recommend applying for leniency, which advice the board will generally follow. Because this scenario plays out in all of the colluding firms at roughly the same time, firms must be concerned that co-conspirators will beat them in the race to be first to apply for leniency.

An application under the Amnesty Plus program would follow a path similar to type B leniency, but instead of the DoJ investigation triggering the events, it is the DoJ's prosecution of collusion in a separate product that sets events in motion. We consider this in more detail in Section 4.6.

In all cases, firms being prosecuted for collusion are asked if there are any other products in which they are colluding. At that point, the board of directors must make decisions related to that. If the firm denies colluding in other products, and if DoJ later incurs the expense to investigate and prosecute the firm's activities in that other product, the firm would not necessarily have the option of applying for leniency in that other product, and individuals might be vulnerable to prosecution for obstruction of justice and/or perjury.[14]

Marx, and White (2011) on the use of economic evidence to prove the existence of a cartel.

[14]For example, consider Hoffman La Roche's participation in cartels in citric acid and vitamins. The cartel in citric acid was prosecuted first. Roche employee Kuno Sommer was asked in deposition related to the prosecution of the citric acid cartel whether he was also involved in a cartel in vitamins. At the time he denied knowledge of any such involvement; however, it was later revealed that "In truth and in fact, the defendant then and there knew that he and other employees of Roche had regularly communicated and met on at least a quarterly basis with competitors, and discussed and agreed to fix, increase and maintain prices, allocate volumes of, and customers for, certain vitamins manufactured by the defendant's employer, Roche, and its corporate coconspirators...." (U.S. v. Dr. Kuno Sommer, U.S. District Court for the Northern District of Texas, Criminal No. 3:99-CR-201-R, Information, par. 17, available at http://www.justice.gov/atr/cases/indx138.htm, accessed October 23, 2012) Roche and others were prosecuted for their involvement in the vitamins cartel, with Roche paying a fine in the U.S. of $500 million, and Kuno Sommer served 4 months in a U.S. prison and paid a fine of $100,000 on charges of violating Section I of the Sherman Act and perjury (making false,

Because leniency applications are made by a firm's board of directors, informed by advice from outside legal counsel, and because the individuals involved in and aware of collusion are typically the managers within a firm who face losing their job and potentially more severe penalties if collusion is uncovered regardless of leniency, leniency applications would typically not occur in the absence of one of the three triggers mentioned above. In particular, one would typically not expect a board of directors to authorize a costly internal investigation by outside counsel to preemptively investigate whether or not the firm is engaged in collusion in the absence of either internal revelations of collusive conduct, an external investigation, or prosecution in another product.

We consider a model that focuses on leniency applications that are triggered either by the initiation of a DoJ investigation (type B leniency) or by the prosecution of a firm for collusion in a separate product. Whether the cartel is successfully prosecuted depends on a number of factors, including (i) whether the potential existence of the cartel comes to the attention of the competition authority, (ii) the strength of the evidence uncovered by the competition authority's investigation, and (iii) whether cartel members apply for leniency. If more than one cartel member applies for leniency, then only one, chosen at random, is designated as receiving leniency (in Section 4.6 we consider the effects of allowing multiple firms to receive fine discounts). If a cartel is successfully prosecuted, we assume collusion ends, and so the profits of all cartel members are reduced by the amount of the collusive gain. In addition, cartel members not covered by the leniency policy are fined.

We show that the incentives for leniency application and hence the probability of successful prosecutions are affected by linkages across markets in the antitrust leniency program. Specifically, an antitrust leniency program that asks firms convicted of collusion to attest to whether or not they are colluding in any other product markets can increase leniency applications in the first product investigated but reduces the probability of prosecution in the other products. Such a linkage in the leniency program can create incentives for firms to form sacrificial cartels and apply for le-

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fictitious and fraudulent statements and representations as to material facts to law enforcement officials). (DoJ website, "Appendix A: Antitrust Division Selected Criminal Cases April 1, 1996 through September 30, 1999," http://www.justice.gov/atr/public/4523d.htm (accessed November 16, 2012). For the charges against Kuno Sommer, see the DoJ website, Information related to United States v. Dr. Kuno Sommer, http://www.justice.gov/atr/cases/f2400/2454.pdf, accessed November 16, 2012) niency in small products where penalties would be limited in order to reduce the probability of conviction in larger, more valuable products. Similarly, the Amnesty Plus program can create incentives for firms collude in additional products in order to have access to the fine reductions offered by that program.

In addition, we endogenize the probability with which cartels are prosecuted by allowing colluding firms to choose the level of concealment effort. We consider concealment activity that reduces the probability that the competition authority acquires evidence of collusion and so starts an investigation,[15] as well as concealment activity that reduces the probability that an individual firm can produce sufficient evidence through internal investigations to qualify for leniency.[16] We show that cartels optimally respond to the introduction of a leniency program by increasing both types of concealment effort, thereby mitigating the effects of the leniency program in terms of detection and deterrence.

We consider implications for the allocation of antitrust enforcement resources and show that resources directed at investigations and prosecutions are strategic complements for generating convictions and that resources must be devoted to both investigation and prosecution in order for a leniency program to be effective in terms of improving detection and deterrence of cartels. Finally, we show that policies such as Amnesty Plus and cooperation policies that offer fine reductions for firms other

[15] For example, firms might expend additional effort coordinating their claimed justifications for price increases. The European Commission Decision in *Electrical and Mechanical Carbon and Graphite Products* states: "With regard to justifications for price increases, a local meeting in the Netherlands on 19 December 1995 came up with the following agreed explanations to 'justify' an impending price increase: 'Explanation for 4% price increase 1. Environmental requirements cost extra. 2. Increase [in price] of raw materials 3. Wages [increased by] 3%."' (¶108) See also the European Commission Decisions in *Cartonboard*, *Amino Acids*, and *Graphite Electrodes*. (See http://ec.europa.eu/competition/cartels/cases/cases.html.)

[16] For example, colluding firms might expend resources to engage a third party facilitator for the cartel that could manage incriminating evidence. For example, the EC Decision in *Organic Peroxides*, states that the cartel maintained certain documents at the premises of a consulting firm AC Treuhand in Switzerland: "[AC Treuhand] produced, distributed and recollected the so called 'pink' and 'red' papers with the agreed market shares which were, because of their colour, easily distinguishable from other meeting documents and were not allowed to be taken outside the AC Treuhand premises." (EC Decision in *Organic Peroxides* at par.92(b)) One would expect this type of strategy to reduce the ability of cartel firms to be able to produce sufficient evidence to qualify for leniency. In *Organic Peroxides*, there were leniency applications: "[Peroxid Chemie] and Laporte [later Degussa] provided in their submission the original of the initial main agreement of 1971, which they obtained from AC Treuhand while preparing the leniency application. It was printed on pink paper, as were other confidential cartel documents which were not allowed to be taken out of the premises of AC Treuhand." (EC Decision in *Organic Peroxides* at par.83) (http://ec.europa.eu/competition/antitrust/cases/dec_docs/37857/37857_100_1.pdf)

than the first to apply for leniency can reduce incentives for cartel members to apply for leniency. This cost must be weighed against potential benefits when assessing these policies.

There is a substantial economics literature on antitrust leniency.[17] The theoretical literature on leniency, including Chen and Rey (2012), Choi and Gerlach (2012), Lefouili and Roux (2012), Harrington (2008), Chen and Harrington (2007), Buccirossi and Spagnolo (2005), Spagnolo (2004), Motta and Polo (2003), Aubert, Rey, and Kovacic (2006), and Spagnolo (2000), has focused on models of essentially tacit collusion.[18] Although the firms engage in some communication at the initiation of the collusive conduct that generates antitrust liability, the collusive behavior is supported as an equilibrium in a supergame without further communication and without interfirm transactions. In each period firms collude or defect. If they defect, they obtain a large one-time payoff, but the deviation is detected and triggers a reversion to static Nash outcomes. In the context of these models, one can analyze how the range of discount factors or the range of collusive payoffs under which collusion can be supported is affected by various implementations of leniency programs. These papers provide important insights related to the optimal design of leniency programs. In general, these models suggest that the introduction of a leniency program makes it more difficult for firms to support collusion, although they recognize that to the extent that leniency programs reduce expected fines, they may reduce deterrence.

A different approach is taken by Harrington (2011), who considers the case of a cartel that has ended, so deviations from the collusive agreement are no longer an issue, but where the threat remains that firms might disclose the cartel to authorities and apply for leniency. Harrington (2011) assumes, as do we, that the firms face uncertainty over the probability the cartel will be discovered and prosecuted in the absence of a leniency applicant. We differ in our modeling approach, which is based on global games, and in our focus on multi-product colluders.

Other approaches are taken by Brisset and Thomas (2004), who provide an auction-based model, and Motchenkova (2004), who considers an optimal stopping model. For empirical analysis of leniency, see Sokol (2012), Miller (2009), and Stephan (2008), and for experimental results, see Bigoni et al. (2012a,b) and Hinloopen and

[17] For surveys, see Rey (2003) and Spagnolo (2008). See also Wils (2008, Chapter 5).

[18] See Green, Marshall, and Marx (2013) for a discussion of differences between legal versus economic interpretations of tacit collusion.

Soetevent (2008).

The literature has also addressed the potential for the strategic use of leniency by cartels. As stated in Wils (2008, p.137), "[S]uccessful cartels tend to be sophisticated organisations, capable of learning. It is thus safe to assume that cartel participants will try to adapt their organisation to leniency policies, not only so as to minimise the destabilising effect, but also, where possible, to exploit leniency policies to facilitate the creation and maintenance of cartels. This raises the question whether there could be features of leniency programmes that risk being exploited to perverse effects." The potential benefits to cartel of explicitly including applying for leniency as part of their collusive strategy in order to obtain the benefits of reduced fines is considered by Chen and Rey (2012), Chen and Harrington (2007), Spagnolo (2004), and Motta and Polo (2003). This literature suggests that generous leniency programs may be exploited by cartels.

Our approach differs in several ways from the existing literature. First, our focus is on explicit collusion, where we assume that the colluding firms have set up the necessary structures to control secret deviations, such as the pricing allocation, and enforcement structures outlined by Stigler (1964).[19] Second, our focus is on multi-product colluders. Third, we consider the incentives for and effects of concealment effort by a cartel.

Fourth, we take a different approach to addressing the coordination aspect of a leniency game, which commonly results in multiple equilibria. For example, if a firm expects its co-conspirator to apply for leniency, then the firm expects to be prosecuted, so it would typically have an incentive also to apply, hoping to be first in the door avoid paying a fine. But if a firm expects that its co-conspirators will not apply for leniency, then it may be a best response also not to apply if that allows collusive profits to continue. We consider a game of incomplete information and use of the results for global games (see Carlsson and van Damme, 1993a, 1993b; and Morris and Shin, 2002) to solve for the unique Bayesian equilibrium that survives

[19] For further discussion of collusive structures, see Marshall and Marx (2012, Chapter 6). For example, the colluding firms may have taken steps to limit the ability of cartel firms to achieve large one-time payoffs through deviations, for example by putting in place contractual restrictions governing their relationship with the input market that prevent cartel members from being able to expand their output to take advantage of any opportunities they might have for secret price cutting. These provisions, together with effective monitoring structures ensure that any feasible deviation by a cartel member would be small and detected immediately and so could be quickly rectified through interfirm transfers.

iterated elimination of dominated strategies.[20] The theory of global games has shown that in some cases, the existence of multiple equilibria relies on common knowledge of payoffs, but that if players have private information, the equilibrium is unique. The theory of global games presents a natural way to look at the issue of leniency, where each player has two main strategies and where it is natural to view the probability of conviction as not being common knowledge, but known with error by the firms in a cartel. Although the coordination game aspect of leniency applications typically generates multiple equilibria and is a key issue in studying the effects of leniency programs, the global games approach allows us to identify a unique equilibrium.

In Section 2, we present the model and provide a benchmark result for the case without a leniency program. In Section 3, we identify the equilibrium of the stand-alone, follow-up and multi-product leniency games. Section 4 contains results and Section 5 concludes.

2 Model

We consider two symmetric firms that have chosen to form an illegal cartel in two markets. We construct a model to capture the following sequence of events. If a firm comes under investigation by the competition authority in one of the markets in which it operates, the firm's board of directors brings in outside counsel to do an internal investigation. If that investigation does not uncover evidence that would allow a leniency application, which happens with probability $1-\rho$ in the model, then there is no option of applying for leniency. If the internal investigation does uncover evidence, then the investigation also provides outside counsel with a signal θ_{ij} as to the probability τ_j that the cartel would be prosecuted in the absence of any leniency applicant. Outside counsel then makes a presentation to the board of directors advising them on next steps, particularly whether to apply for leniency or

[20] Applications of global games results related to financial market issues include Morris and Shin (1998, 1999), Danielson et al. (2001), Heinemann and Illing (2002), Hellwig (2002), Metz (2002), and Prati and Sbracia (2002). Other contributions to the global games literature include Levin (2001), who examines a global game with overlapping generations, and Chamley (1999) and Angeletos, Hellwig, and Pavan (2007), who consider models of regime change. Frankel, Morris, and Pauzner (2003) prove an equilibrium uniqueness result for a family of dynamic, finite horizon, recursively supermodular, global games. See also extensions by Giannitsarou and Toxvaerd (2009) and Ordoñez (2008). Heinemann, Nagel, and Ockenfels (2004) study global games in an experimental context and obtain results consistent with the global game solution.

not, taking into account the probability of prosecution in the absence of a leniency application by either firm. In this case, the board of directors makes the choice between applying for leniency or not, but at the time of this choice, the board does not know whether the internal investigation at the other firm has uncovered evidence sufficient to allow a leniency application by that firm, and if it has, does not know the choice made by the other firm.

We normalize the firms' payoff when it is successfully prosecuted and fined to be zero and let $\pi_j > 0$ be each firm's collusive gain in product $j \in \{1, 2\}$, including any fines or penalties that the firm is avoiding and would have to pay if it were convicted of collusion. We model the leniency program with the potential for linkage across markets as described below. Consistent with the U.S. experience, we focus on leniency applications that happen after the cartel is under investigation by the competition authority (type B leniency). When the leniency program is in place, we let $L_j = \ell\pi_j$ be the benefit (or penalty discount) from being granted leniency in product j, where $\ell \in (0, 1)$, so that the collusive gain is higher than the leniency benefit. Thus, if a firm is convicted of colluding but is granted leniency, then it obtains a payoff L_j instead of zero.[21]

Table 4: Payoffs in the model for product i

Outcome	**Payoffs**
Caught and pay fines	0
Caught and granted leniency	$\ell\pi_i$
Not caught	π_i

The timeline is as follows:

1. In the first round, one product $j \in \{1, 2\}$ is randomly selected and then the stand-alone leniency game is played for product j.

   The *stand-alone leniency game* has four stages:

   (a) In the first stage, both firms observe signal $s_j \in \{0, 1\}$, where $\Pr(s_j = 1) = h$ for $h \in (0, 1)$ (later we relate h to concealment effort by the cartel). The

[21]In the United States, firms receiving leniency may still be subject to penalties from civil litigation; however, exposure to those penalties is reduced for leniency applicants. "Under the Antitrust Criminal Penalty Enhancement and Reform Act of 2004, Pub. L. No. 108-237, Title 2, §§ 211-214, 118 Stat. 661, 666-668, a leniency applicant may qualify for detrebling of damages if the applicant cooperates with plaintiffs in their civil actions while the applicant's former co-conspirators will remain liable for treble damages on a joint and several basis." (Hammond and Barnett, 2008, p.18.)

realization $s_j = 1$ denotes that the competition authority has received some evidence about illegal antitrust activity in product j and has started an investigation, while $s_j = 0$ means that this has not happened.[22]

(b) In the second stage, nothing happens if $s_j = 0$, but if $s_j = 1$, each firm brings in outside counsel to do an internal investigation. The internal investigation uncovers evidence sufficient to support a leniency application with probability $\rho \in (0, 1)$ (later we relate ρ to concealment effort by the cartel), in which case the outside counsel observes a conditionally independent random variable θ_{ij} uniformly distributed in the interval $[\tau_j - \epsilon, \tau_j + \epsilon]$, where $\epsilon > 0$, centered on the realized value of the random variable τ_j. We will think of ϵ as "small", so that τ_j is "almost" perfectly observed by each firm. Later we will focus on the limit as $\epsilon \downarrow 0$. As we shall see, τ_j determines the probability of being convicted of collusion.

(c) In the third stage, nothing happens if $s_j = 0$ or if $s_j = 1$ and the internal investigation did not uncover evidence sufficient to support a leniency application. But if $s_j = 1$ and the internal investigation did uncover such evidence, then the outside counsel advises the board of directors on whether to apply for leniency or not. If only one firm applies for leniency, it receives leniency. If both firms apply for leniency, one (and only one) is randomly designated as receiving leniency.

(d) In the fourth stage, the competition authority concludes its investigation after observing an additional signal $v_j \in \{0, 1\}$ indicating the strength of the case; $v_j = 1$ signifies that the authority has enough evidence to convict the firms, while $v_j = 0$ denotes insufficient evidence and the need to drop the case. We assume $v_j = 1$ if there is at least one leniency applicant. If there is no leniency applicant, $\Pr(v_j = 1 \mid s_j = 0) = 0$ and $\Pr(v_j = 1 \mid s_j = 1) = \tau_j$. From the point of view of the firms, τ_j is a random variable uniformly distributed in the interval $[\underline{\tau}, \overline{\tau}]$; let $\tau^E = (\underline{\tau} + \overline{\tau})/2$ be the expected value of τ_j.

[22] The U.S. Department of Justice's "Frequently Asked Questions Regarding the Antitrust Division's Leniency Program and Model Leniency Letters" (2008, p.5) states that "A company will qualify for leniency even after the Division has received information about the illegal antitrust activity, whether this is before or after an investigation is formally opened, if the following [seven] conditions are met: ...." (available at http://www.justice.gov/atr/public/criminal/239583.htm, accessed October 23, 2012)

2. In the second round, with unlinked leniency the stand-alone game is played for product $j' \neq j$. With linked leniency, if $v_j = 0$, then the stand-alone leniency game is played for product $j' \neq j$, but if $v_j = 1$, then the follow-up leniency game is played for product j'. In the follow-up leniency game, firms prosecuted in product j are asked about potential collusion in product j' and must decide whether to apply for leniency or not without having observed the signal $s_{j'}$.

   The *follow-up leniency game* has four stages:

   (a) In the first stage, each firm brings in outside counsel to do an internal investigation. The internal investigation uncovers evidence sufficient to support a leniency application with probability $\rho > 0$, in which case the outside counsel observes a conditionally independent random variable $\theta_{ij'}$ centered on the realized value of the random variable $\tau_{j'}$.

   (b) In the second stage, if the internal investigation uncovered evidence sufficient to support a leniency application, then the board decides whether to apply for leniency or not (not knowing whether it will come under investigation in the absence of a leniency application).

   (c) In the third stage, if no firm has applied for leniency, then the competition authority receives evidence about illegal antitrust activity, $s_{j'} = 1$, with probability h.

   (d) In the fourth stage, the competition authority concludes its investigation after observing the additional signal $v_{j'} \in \{0, 1\}$, as in the single product game.

We end this section by looking at the benchmark case in which there is a single product and no possibility for colluding firms to apply for leniency; that is, the "game" played consists of the stand-alone leniency game without the third stage. In the absence of a leniency program, the cartel is convicted in each product with probability $\Psi^N = h^N \tau^E$. A cartel firm's expected payoff in product i without a leniency program is $V^N \pi_i$, where $V^N = (1 - \Psi^N)$.

3 Equilibrium

We now study the case when there is a leniency program in place. We begin by considering the second round in which either the stand-alone leniency game or the follow-up leniency game is played.

In Section 3.1, we consider the stand-alone leniency game. We show that firm i applies for leniency when the investigation uncovers evidence if the signal θ_{ij} regarding the probability of successful prosecution is sufficiently high. On the contrary, if the signal is sufficiently low, then the firm does not apply for leniency.

In Section 3.2, we consider the follow-up leniency game. In this case, firms must make their choices prior to learning whether the competition authority will obtain evidence of collusion on its own. In that game, for certain parameter values, the firms never apply for leniency.

In Section 3.3, we consider the full multi-product leniency game.

3.1 Stand-alone leniency game

We begin by considering the case in which the stand-alone leniency game is played in the final remaining product. For the purposes of this sub-section, we denote the final product as product j.

If $s_j = 0$, the authority has no evidence and firms are not prosecuted; each firm gets a payoff of π_j. If $s_j = 1$, the two firms become aware that the competition authority has some evidence of collusion. The firms start internal investigations, but each investigation yields insufficient evidence to support a leniency application with probability $1-\rho$. With probability ρ, the firm plays the following simultaneous move game in which they decide whether to apply for leniency (L) or not (N). For a given τ_j the game is summarized by the following normal form (since the game is symmetric, we only report the payoff of the row player):

	L	N
L	$(1-\frac{\rho}{2})L_j$	L_j
N	$(1-\rho)(1-\tau_j)\pi_j$	$(1-\tau_j)\pi_j$

For example, for the upper left cell, if firm 1 applies for leniency, it receives leniency if the investigation at the other firm did not uncover sufficient evidence to apply (probability $1-\rho$) and receives leniency with probability $\frac{1}{2}$ if the other firm did uncover sufficient evidence (probability ρ). Thus, the payoff in that case is $(1-\rho+\frac{\rho}{2})L_j = (1-\frac{\rho}{2})L_j$. For the lower left cell, firm 1 is not prosecuted as long as the other firm does not uncover sufficient evidence to apply for leniency (probability $1-\rho$) and the strength of the case is such that the competition authority cannot successfully prosecute (probability $1-\tau_j$).

For this game, we can distinguish between the following four cases:

1. If $(1-\frac{\rho}{2})L_j > (1-\rho)(1-\tau_j)\pi_j$ and $L_j > (1-\tau_j)\pi_j$, then leniency is a strictly dominant strategy and hence (L, L) is the unique Nash equilibrium. These conditions hold if and only if

$$\tau_j > 1-\ell.$$

2. If $(1-\frac{\rho}{2})L_j > (1-\rho)(1-\tau_j)\pi_j$, $L_j < (1-\tau_j)\pi_j$, and $(1-\frac{\rho}{2})L_j - (1-\rho)(1-\tau_j)\pi_j > (1-\tau_j)\pi_j - L_j$, then there are two pure strategy Nash equilibria (L, L) and (N, N), and equilibrium (L, L) is risk dominant. These conditions hold if and only if
$$1-\frac{4-\rho}{4-2\rho}\ell < \tau_j < 1-\ell.$$

3. If $(1-\frac{\rho}{2})L_j > (1-\rho)(1-\tau_j)\pi_j$, $L_j < (1-\tau_j)\pi_j$, and $(1-\frac{\rho}{2})L_j - (1-\rho)(1-\tau_j)\pi_j < (1-\tau_j)\pi_j - L_j$, then there are two pure strategy Nash equilibria (L, L) and (N, N), and (N, N) is risk dominant. These conditions hold if and only if
$$1-\frac{2-\rho}{2-2\rho}\ell < \tau_j < 1-\frac{4-\rho}{4-2\rho}\ell.$$

4. If $(1-\frac{\rho}{2})L_j < (1-\rho)(1-\tau_j)\pi_j$ and $L_j < (1-\tau_j)\pi_j$, then no leniency is a dominant strategy and hence (N, N) is the unique Nash equilibrium. These conditions hold if and only if

$$\tau_j < 1-\frac{2-\rho}{2-2\rho}\ell.$$

As this last condition shows, without some probability that the competition authority prosecutes the cartel in the absence of a leniency application, it is a dominant strategy for firms not to apply for leniency. Thus, as remarked by Wils (2008, p.130), "Indeed, leniency can only work if the companies and individuals concerned perceive a risk that the competition authorities will detect and establish the antitrust violation without recourse to leniency." However, when there is a threat of prosecution in the absence of a leniency application, the threat that a co-conspirator may apply for leniency increases leniency applications—if it were known that the rival could not apply for leniency, perhaps because it would be viewed as a ringleader or coercing others to join and so not eligible for leniency, then the firm applies for leniency if and only if $L_j > (1-\tau_j)\pi_j$, i.e., $\tau_j > 1-\ell$. However, as shown below in Proposition 1, with the threat that a co-conspirator may apply, a firm applies for leniency for a larger range of values for τ_j. This again echoes statements in Wils (2008, p.130): "In the case of collective violations such as cartels, and if leniency policies are well designed, in that immunity is granted only to the first co-conspirator to come forward, and reductions in penalties are linked to the timing of the cooperation as compared to the other co-conspirators, companies and individuals may decide to cooperate out of fear that a co-conspirator may do so before them. Such a 'race to cooperate' may amplify the positive effects of leniency, but again such a race can only start if there is a risk that the competition authorities will detect and establish the antitrust violation without recourse to leniency, or at least a belief by at least one of the conspirators that at least one of the other co-conspirators may believe that there is such a risk."

In order to focus on the richest environment, we will assume that the parameter configuration does not rule out any case. (Note that, for example, if $\rho = 1$, then N cannot be a dominant strategy.) Thus, we assume that the highest possible value of τ_j is such that the leniency program is certainly effective and that the lowest possible value of τ_j is such that the leniency program is ineffective. We can write this assumption as follows.

Assumption $A0$: $1-\overline{\tau} < \ell < (1-\underline{\tau})\frac{2-2\rho}{2-\rho}$.

Throughout the remainder of the paper, we maintain assumption $A0$.

We can think of the signal θ_{ij} received by firm i as i's type. The strategy of firm i can then by represented as the probability $\alpha_{ij}(\theta_{ij})$ with which the firm chooses pure strategy L after observing signal θ_{ij}.

We are now in a position to prove the following result, which exploits the fact that τ_j is a random variable that is imperfectly observed by the firms. Letting $\tau^* \equiv 1-\frac{4-\rho}{4-2\rho}\ell$, we have the following result.

Proposition 1 *In the stand-alone leniency game, for ϵ sufficiently small, the subgame taking place after a signal $s_j = 1$ has a unique Bayesian equilibrium that survives the iterated elimination of strictly dominated strategies. In such an equilibrium, each firm applies for leniency if evidence permits, $\alpha_{ij}(\theta_{ij}) = 1$, for all $\theta_{ij} > \tau^*$, but does not, $\alpha_{ij}(\theta_{ij}) = 0$, for all $\theta_{ij} < \tau^*$.*

Proof. If i observes $\theta_{ij} \in [\tau_j - \varepsilon, \tau_j + \varepsilon]$, for $\varepsilon > 0$, i's posterior on τ will be uniform on $[\theta_{ij} - \varepsilon, \theta_{ij} + \varepsilon]$. The conditional distribution of the other firm's observation will be symmetric around θ_{ij} with support $[\theta_{ij} - 2\varepsilon, \theta_{ij} + 2\varepsilon]$. If $\varepsilon < \frac{\overline{\tau}-(1-\ell)}{2}$, which is feasible given assumption $A1$, and $\theta_{ij} > 1 - \ell$, then i's conditionally expected payoff from L is greater than from N regardless of the rival's choice, so L is conditionally (strictly) dominant for i when firm i observes $\theta_{ij} > 1 - \ell$.

If firm 2 plays L for $\theta_{2j} > 1 - \ell$, then firm 1 observing $\theta_{1j} = 1 - \ell$ must assign at least probability $\frac{1}{2}$ to firm 2's choosing L. Let $\alpha \geq \frac{1}{2}$ be the probability which firm 1 assigns to firm 2 choosing L. Firm 1's expected payoff from L is

$$\alpha(1 - \frac{\rho}{2})L_j + (1 - \alpha)L_j = \left(1 - \frac{\alpha\rho}{2}\right)\ell\pi_j,$$

and firm 1's conditionally expected payoff from N is

$$\alpha(1 - \rho)(1 - \theta_{1j})\pi_j + (1 - \alpha)(1 - \theta_{1j})\pi_j = (1 - \alpha\rho)\ell\pi_j,$$

where the equality uses $\theta_{1j} = 1 - \ell$, which is less than the expected payoff from L. Thus, N can be excluded by iterated dominance for $\theta_{ij} = 1 - \ell$.

Let θ^*_{ij} be the largest observation for which L cannot be established by iterated dominance, i.e., θ^*_{ij} is the lower bound on the iterated dominance region. By symmetry, $\theta^*_{1j} = \theta^*_{2j} = \theta^*_j$. Iterated dominance requires firm 2 to play L for any $\theta_{2j} > \theta^*_j$, so if firm 1 observes θ^*_j, it will assign at least probability $\frac{1}{2}$ to firm 2's choosing L. Let $\alpha \geq \frac{1}{2}$ be the probability with which firm 1 assigns to firm 2's choosing L. By the definition of θ^*_j, it must be that firm 1's conditionally expected payoff from N is greater than or equal to its expected payoff from L, i.e.,

$$\begin{aligned} & \alpha(1 - \frac{\rho}{2})L_j + (1 - \alpha)L_j \\ \leq\ & \alpha(1 - \rho)\left(1 - \theta^*_j\right)\pi_j + (1 - \alpha)\left(1 - \theta^*_j\right)\pi_j, \end{aligned}$$

which we can rewrite as

$$\left(1-\frac{\alpha\rho}{2}\right)\ell \leq (1-\alpha\rho)\left(1-\theta_j^*\right),$$

which we can rewrite as

$$\theta_j^* \leq 1-\frac{2-\alpha\rho}{2-2\alpha\rho}\ell \leq 1-\frac{4-\rho}{4-2\rho}\ell = \tau^*,$$

where the second inequality follows from $\alpha \geq \frac{1}{2}$.

Similarly, if $\varepsilon < \left(1-\frac{2-\rho}{2-2\rho}\ell - \underline{\tau}\right)\frac{1}{2}$, which is feasible given assumption $A0$, and $\theta_{ij} < 1-\frac{2-\rho}{2-2\rho}\ell$, then i's conditionally expected payoff from N is greater than from L regardless of the rival's choice, so N is conditionally (strictly) dominant for i when firm i observes $\theta_{ij} < 1-\frac{2-\rho}{2-2\rho}\ell$.

If firm 2 plays N for $\theta_{2j} < 1-\frac{2-\rho}{2-2\rho}\ell$, then firm 1 observing $\theta_{1j} = 1-\frac{2-\rho}{2-2\rho}\ell$ must assign at least probability $\frac{1}{2}$ to firm 2's choosing N. Let $\alpha \geq \frac{1}{2}$ be the probability that firm 1 assigns to firm 2 choosing N. Firm 1's expected payoff from L is once again $\left(1-\frac{\alpha\rho}{2}\right)\ell\pi_j$, and firm 1's conditionally expected payoff from N is

$$\begin{aligned} & \alpha(1-\rho)\left(1-\theta_{1j}\right)\pi_j + (1-\alpha)\left(1-\theta_{1j}\right)\pi_j \\ = \; & (1-\alpha\rho)\frac{2-\rho}{2-2\rho}\ell\pi_j, \end{aligned}$$

where the equality uses $\theta_{1j} = 1-\frac{2-\rho}{2-2\rho}\ell$, which one can show is greater than the expected payoff from L. Thus, L can be excluded by iterated dominance for $\theta_{ij} = 1-\frac{2-\rho}{2-2\rho}\ell$.

Let θ_{ij}^{**} be the smallest observation for which N cannot be established by iterated dominance, i.e., θ_{ij}^{**} is the upper bound on the iterated dominance region. By symmetry, $\theta_{1j}^{**} = \theta_{2j}^{**1} = \theta_j^{**}$. Iterated dominance requires firm 2 to play N for any $\theta_{2j} < \theta_j^{**}$, so if firm 1 observes θ_j^{**}, it will assign at least probability $\frac{1}{2}$ to firm 2's choosing N. Let $\alpha \geq \frac{1}{2}$ be the probability with which firm 1 assigns to firm 2's choosing N. By the definition of θ_j^{**}, it must be that firm 1's conditionally expected payoff from L is greater than or equal to its expected payoff from N, i.e.,

$$\begin{aligned} & (1-\alpha)(1-\frac{\rho}{2})L_j + \alpha L_j \\ \geq \; & (1-\alpha)(1-\rho)\left(1-\theta_j^{**}\right)\pi_j + \alpha\left(1-\theta_j^{**}\right)\pi_j, \end{aligned}$$

which we can rewrite as

$$\left(1-\frac{(1-\alpha)\rho}{2}\right)\ell \geq (1-(1-\alpha)\rho)\left(1-\theta_j^{**}\right),$$

which we can rewrite as

$$\theta_j^{**} \geq 1-\frac{2-(1-\alpha)\rho}{2-2(1-\alpha)\rho}\ell \geq 1-\frac{4-\rho}{4-2\rho}\ell = \tau^*,$$

where the second inequality follows from $\alpha \geq \frac{1}{2}$.

Since $\theta_j^{**} \leq \theta_j^*$ and $\theta_j^{**} \geq \tau^* \geq \theta_j^*$, it follows that $\theta_j^{**} = \tau^* = \theta_j^*$. The result then follows. ■

As Proposition 1 shows, depending on the signals firms receive, firms for which leniency is feasible may choose to apply for leniency or may not. In the absence of assumption $A0$, we cannot guarantee that whenever (L, L) is a Nash equilibrium for certain parameter values, it is also the case that L is a dominant strategy for certain parameter values (and similarly for strategy N). If there is not a region where the strategies are dominant, then the iterated elimination of dominated strategies that was used to identify a unique equilibrium for all signals in Proposition 1 no longer delivers that unique outcome.[23]

Henceforth, when computing payoffs and probabilities of successful prosecution, we take the limit as $\epsilon \downarrow 0$, with the implication that the firms are coordinated on either both applying for leniency when that is feasible or both not applying for leniency.

We can compute the ex-ante probability that the cartel will be convicted in a product in the unlinked leniency game. It is:

$$\Psi^U = h\left[1-(1-\rho)^2(1-\tau^E)-\rho(2-\rho)\int_{\underline{\tau}}^{\tau^*}\frac{1-\tau}{\overline{\tau}-\underline{\tau}}d\tau\right]. \tag{1}$$

To understand this expression, note that, conditional on the competition authority acquiring evidence, which occurs with probability h, the cartel is not convicted if

[23] For example, if $\rho = 1$ so that it is always feasible for firms under investigation to apply for leniency, then assumption $A0$ is not satisfied. It is never a dominant strategy not to apply for leniency, although not applying for leniency is risk dominant if $\tau_j < 1-\frac{3}{2}\ell$. If $\underline{\tau} < 1-\frac{3}{2}\ell$ so that this case is a possibility, then we are in position where the global games logic of Proposition 1 does not pin down the equilibrium.

neither firm finds it feasible to apply for leniency and then the competition authority is unable to convict, which occurs with probability $(1-\rho)^2(1-\tau^E)$, which is the second term in the square brackets, or if at least one firm finds it feasible to apply for leniency (probability $\rho(2-\rho)$) but τ is less than τ^*, which explains the last term in the square brackets.

The expected payoff to a cartel firm from product j is $V^U\pi_j$, where

$$V^U = 1 - \Psi^U + h\rho\,(2-\rho)\int_{\tau^*}^{\overline{\tau}} \frac{\frac{1}{2}\ell}{\overline{\tau}-\underline{\tau}}d\tau. \tag{2}$$

To understand this expression, note that a firm gets π_j with probability $1-\Psi^U$, but gets ℓ if only it applies for leniency (probability $h\rho(1-\rho)\Pr(\tau>\tau^*)$) and $\frac{1}{2}\ell$ if both firms apply for leniency (probability $h\rho^2\Pr(\tau>\tau^*)$), which generates the final term in (2).

3.2 Follow-up leniency game

In the follow-up leniency game, firms uncovering sufficient evidence from an internal investigation in order to consider applying for leniency must decide before the competition authority has collected any incriminating evidence; that is, before observing the signal s_j. For a given τ_j, the game is summarized by the following normal form:

	L	N
L	$(1-\frac{\rho}{2})L_j$	L_j
N	$(1-\rho)(1-h\tau_j)\,\pi_j$	$(1-h\tau_j)\,\pi_j$

It is immediate to see that the structure of the game is the same as in the stand-alone leniency game. The only difference is that now $h\tau_j$ replaces τ_j.

The condition that guarantees that for some parameter values N is a dominant strategy is

$$\underline{\tau} < \left(1 - \frac{2-\rho}{2-2\rho}\ell\right)\frac{1}{h},$$

which holds under assumption $A0$. In what follows we assume that the probability h that the competition authority acquires evidence of collusion on its own is relatively low, so that in follow-up game action N is risk dominant (and hence L is never a dominant strategy):

Assumption A1: $\overline{\tau}h < \tau^*$.

In Section 4.4, we endogenize the probability that the cartel comes to the attention of the competition authority, h, by relating it to concealment effort by the cartel and show that the cartel has an incentive to ensure that assumption $A1$ holds.

We are now in a position to state a result that parallels Proposition 1. The proof is omitted.

Proposition 2 *Under assumption* $A1$*, for* ϵ *sufficiently small, the follow-up leniency game has a unique Bayesian equilibrium that survives the iterated elimination of strictly dominated strategies. In that equilibrium, no firm applies for leniency,* $\alpha_{ij}(\theta_{ij}) = 0$*, for all* θ_{ij}*.*

Using Proposition 2, we can compute the probability that the cartel will be convicted in the follow-up game under assumption $A1$:

$$\Psi^F = 1 - \int_{\underline{\tau}}^{\overline{\tau}} \frac{1 - h\tau}{\overline{\tau} - \underline{\tau}} d\tau = h\tau^E. \tag{3}$$

Under assumption $A1$, the expected payoff of a cartel firm is $V^F \pi_j$, where

$$V^F = 1 - \Psi^F. \tag{4}$$

Under assumption $A1$, the probability of successful prosecution is greater and the expected payoff to the cartel is lower in the stand-alone leniency game than in the follow-up leniency game. Thus, firms prefer the follow-up leniency game to the stand-alone leniency game. The proof is contained in Appendix A, as are all other omitted proofs.

Lemma 1 *Under assumption* $A1$*,* $\Psi^U > \Psi^F$*, and* $V^U - V^F = h\left(\frac{\partial V^U}{\partial h} - \frac{\partial V^F}{\partial h}\right) < 0$.

3.3 Linked leniency

In the case of an unlinked leniency program, the stand-alone leniency game is always played in each of the two products. Since we have assumed that there are no other spill-overs between the two products (e.g., we have abstracted from correlations among the probabilities of successful investigation, etc.), and since there is a unique equilibrium in the stand-alone game, if the competition authority does not impose any links between applying for leniency in the two products, then it follows from backwards induction that the stand-alone equilibrium will apply to each product. Behavior in one product has no impact on the other product.

This is no longer true in the case of a linked leniency program. With a linked leniency program, firms prosecuted for collusion in the first product must choose whether to apply for leniency in the second product before observing whether the competition authority has received information about illegal antitrust activity in the second product (i.e., before s_2 is realized). Thus, after a conviction in the first product, firms must play the follow-up leniency game in the second product, which gives each of them an expected payoff $V^F\pi_2$. If a conviction has not taken place in the first product, then in the second product firms will play the stand-alone leniency game and obtain the expected continuation payoff $V^U\pi_2$.

Thus, we can use the continuation equilibrium payoff of the firms in product 2 to write the payoff matrix of the leniency game in the first product conditional on an internal investigation producing sufficient evidence to support a leniency application as follows:

	L	N
L	$(1-\frac{\rho}{2})L_1 + V^F\pi_2$	$L_1 + V^F\pi_2$
N	$(1-\rho)(1-\tau_1)\left(\pi_1 + V^U\pi_2\right) + (\rho + \tau_1 - \rho\tau_1)V^F\pi_2$	$(1-\tau_1)(\pi_1 + V^U\pi_2) + \tau_1 V^F\pi_2$

There are two cases to consider. If $\frac{\pi_2}{\pi_1} > \frac{1}{V^F - V^U}$, then L is dominant.[24] If $\frac{\pi_2}{\pi_1} < \frac{1}{V^F - V^U}$, then L is risk dominant if

$$\tau_1 > 1 - \frac{4-\rho}{4-2\rho}\frac{\ell}{1-(V^F - V^U)\frac{\pi_2}{\pi_1}},$$

[24] To see this, note that L is dominant if

$$(1-\frac{\rho}{2})L_1 + V^F\pi_2 > (1-\rho)(1-\tau_1)\left(\pi_1 + V^U\pi_2\right) + (\rho + \tau_1 - \rho\tau_1)V^F\pi_2,$$

which we can rewrite as $\frac{1}{V^F - V^U}\left(1 - \frac{2-\rho}{2-2\rho}\frac{1}{1-\tau_1}\ell\right) < \frac{\pi_2}{\pi_1}$, and $L_1 + V^F\pi_2 > (1-\tau_1)(\pi_1 + V^U\pi_2) + \tau_1 V^F\pi_2$, which we can rewrite as $\frac{1}{V^F - V^U}\left(1 - \frac{1}{1-\tau_1}\ell\right) < \frac{\pi_2}{\pi_1}$, which is sufficient for L to be dominant.

N is risk dominant if

$$\tau_1 < 1 - \frac{4-\rho}{4-2\rho} \frac{\ell}{1-(V^F - V^U)\frac{\pi_2}{\pi_1}},$$

and N is dominant if

$$\tau_1 < 1 - \frac{2-\rho}{2-2\rho} \frac{\ell}{1-(V^F - V^U)\frac{\pi_2}{\pi_1}}.$$

In what follows, we let

$$\tau^{**} \equiv \begin{cases} \underline{\tau}, & \text{if } \frac{\pi_2}{\pi_1} > \frac{1}{V^F - V^U} \\ \min\left\{ \max\left\{ \underline{\tau}, 1 - \frac{4-\rho}{4-2\rho} \frac{\ell}{1-(V^F-V^U)\frac{\pi_2}{\pi_1}} \right\}, \overline{\tau} \right\}, & \text{otherwise.} \end{cases}$$

Proposition 3 *Under assumption A1, for ϵ sufficiently small, the model of two products with a linked leniency program has a unique Bayesian equilibrium that survives the iterated elimination of strictly dominated strategies. In such an equilibrium, each firm applies for leniency if evidence permits, $\alpha_{ij}(\theta_{ij}) = 1$, for all $\theta_{ij} > \tau^{**}$, but does not, $\alpha_{ij}(\theta_{ij}) = 0$, for all $\theta_{ij} < \tau^{**}$. If $v_1 = 0$, then in the second product following $s_2 = 1$, when evidence permits each firm applies for leniency, $\alpha_{i2}(\theta_{i2}) = 1$, for all $\theta_{i2} > \tau^*$, but does not, $\alpha_{i2}(\theta_{i2}) = 0$, for all $\theta_{i2} < \tau^*$; but if $v_1 = 1$, then neither firm applies for leniency.*

Proposition 3 completes our analysis of the equilibrium of the game and shows that under a linked leniency program, conditional on $s_1 = 1$, the probability that some firm applies for leniency in product 1 is $\rho(2-\rho)\left(\int_{\tau^{**}}^{\overline{\tau}} \frac{1}{\overline{\tau}-\underline{\tau}} d\tau\right)$. This is in contrast to the case of unlinked leniency, where the probability that some firm applies for leniency is $\rho(2-\rho)\left(\int_{\tau^{*}}^{\overline{\tau}} \frac{1}{\overline{\tau}-\underline{\tau}} d\tau\right)$, which is lower by the definitions of τ^* and τ^{**}. Thus, conditional on $s_1 = 1$, the firms apply for leniency in product 1 with higher probability under a linked leniency program than an unlinked leniency program.

As this suggests, a cartel is more likely to be convicted in the first product with linked leniency than with unlinked leniency. To formalize this, we define the ex-ante probability that the cartel will be prosecuted and convicted in the first product:

$$\Psi_1^L = h\left[1 - (1-\rho)^2(1-\tau^E) - \rho(2-\rho)\int_{\underline{\tau}}^{\tau^{**}} \frac{1-\tau}{\overline{\tau}-\underline{\tau}} d\tau\right]. \tag{5}$$

Thus, in the multi-product game, the probability that the cartel will be prosecuted and convicted in the second product is

$$\Psi_2^L = \Psi_1^L \Psi^F + (1 - \Psi_1^L)\Psi^U. \tag{6}$$

The expected payoff from the first product in the multi-product game is $V_1^L \pi_1$, where

$$V_1^L = 1 - \Psi_1^L + \frac{1}{2} h\rho\,(2-\rho) \int_{\tau^{**}}^{\overline{\tau}} \frac{\ell}{\overline{\tau} - \underline{\tau}} d\tau.$$

The total payoff in the multi-product game is

$$V^L = V_1^L \pi_1 + \Psi_1^L V^F \pi_2 + (1 - \Psi_1^L) V^U \pi_2.$$

In the next section we describe the key results emerging from this model.

4 Results

4.1 Leniency contributes to prosecution and preemption effects

As shown in Proposition 1, and assuming the cartel firms receive accurate signals of the probability of prosecution in the absence of a leniency applicant, then once a cartel comes under investigation, firms apply for leniency whenever the probability of prosecution without a leniency applicant, τ, is greater than the threshold τ^* and do not apply when it is less than τ^*. Figure 1 illustrates the relation between τ and the dominant or risk dominant strategies in the standalone leniency game for particular parameter values. As in Harrington (2011), we can analyze the game in terms of the prosecution and preemption effects created by leniency.

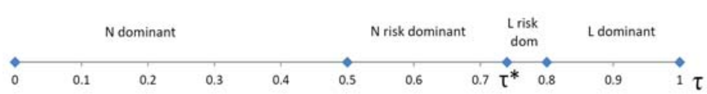

Figure 1: Dominant and risk dominant strategies in relation to τ ($\rho = .75$, $\ell = .2$)

If τ is sufficiently large that L is the dominant strategy, then a firm will seek leniency even if it expects that the other firm will not. This is the prosecution effect.

Firms have an incentive to apply for leniency in order to avoid the penalties associated with being prosecuted, which for high τ is relatively likely even in the absence of a leniency applicant. If τ is in the range greater than τ^* where there are two Nash equilibria of the complete information game, but L is the risk dominant strategy, then a firm will seek leniency only if it expects the other firm to apply for leniency. This is the preemption effect. A firm only prefers leniency as a means to preempt the leniency application of the other firm.

An increase in the leniency discount, ℓ, increases the prosecution effect and increases the preemption effect. Thus, there is a double benefit from increasing the leniency discount.[25] An increase in the probability that an internal investigation uncovers evidence, ρ, increases the preemption effect. If it is more likely that a co-conspirator has maintained incriminating evidence in house, then a firm has a greater incentive to apply for leniency. This suggests that leniency programs can be made more effective if a competition authority can take steps that limit the ability of cartels to outsource the running of the cartel and control of incriminating evidence to third-party facilitators, such as the firm AC Treuhand listed in Table 3.[26]

4.2 Strategic reactions to linked leniency can reduce detection and deterrence

In the linked leniency game, firms have an additional incentive to apply for leniency in the first product because conviction in the first product delivers the benefit to the cartel of an increased payoff in the second product by changing the game in the second product from the stand-alone leniency game to the follow-up leniency game. As a result, linking the leniency policy increases convictions in the first product but decreases convictions in the second product relative to an unlinked leniency policy. The "punishment" of being asked about cartels in other products offers value to the cartel firms because it allows a better outcome for the cartel in the second product.

Proposition 4 *Under assumption A*1, *relative to unlinked leniency, under a linked leniency program: (i) firms are more likely to apply for leniency and more likely to be*

[25] See Harrington (2011) on the "multiplier effect" of a more aggressive competition authority.

[26] See the EC decisions in *Organic Peroxides* and *Heat Stabilisers* for descriptions of the role that AC Treuhand played in supporting those cartels, including maintaining cartel documents at their premises in Zurich, Switzerland.

convicted in the first product, (ii) firms are less likely to apply for leniency and less likely to be convicted in the second product, and (iii) firms obtain a lower expected payoff in the first product.

Proof. We show in the appendix that $\Psi_2^L < \Psi^U < \Psi_1^L$ and $V_1^L < V^U$.

Proposition 4 suggests a potential strategic use of leniency by multi-product cartels. Firms engaged in collusion in multiple products may be able to make use of a leniency application in a less profitable product in order to commit to the follow-up game for the more profitable product, with the associated equilibrium outcome that firms do not apply for leniency in the more profitable product. This raises concerns that, conditional on being prosecuted, multi-product colluders may have an incentive to manipulate which product is prosecuted first.

Under assumption $A1$, linking the leniency programs in the two products generates a trade-off. It increases the probability of a leniency application in the first product, but it decreases it in the second product. In addition, it decreases the cartel's payoff in the first product and increases it in the second product. This suggests that the competition authority has an incentive to attend to the more profitable product first, while, on the contrary, firms have an incentive to apply for leniency in the less profitable product first. Clearly a multi-product cartel has an incentive to manipulate the order in which products are approached by the competition authority to the extent that is possible, potentially engaging in collusion in a minor product and revealing the existence of the cartel in order to decrease the probability of prosecution in the more valuable product. Thus, the linking of leniency across products can potentially cause more cartels to form than if leniency applications were not linked. In particular, minor products that were not worth cartelizing with unlinked leniency, perhaps because the incremental value from cartelization was insufficient given the costs of establishing the required collusive structures, may be worth cartelizing in an environment with linked leniency because the additional cartels provide the potential benefit of insulating more valuable products from leniency applications. The cartelization of markets that would not have been cartelized otherwise means that prices increase in these markets and consumer surplus decreases. In this way, by linking leniency across markets, a competition authority can cause consumer surplus to decrease.

Thus, when one considers the strategic use (abuse) of a linked leniency program by a multi-product cartel through the creation of sacrificial cartels to protect larger, more valuable products, linking leniency can reduce detection and reduce deterrence, i.e., increase the profits from collusion.

Under a linked leniency program, applying for leniency in the first product plays the role of a commitment device; under assumption $A1$, firms convicted in one product are able to commit not to apply for leniency in the second product since that is the unique equilibrium of the follow-up game, indeed a dominant strategy.

The results for linked leniency obtain because linked leniency offers cartels a commitment device, essentially allowing them to commit not to apply for leniency in other products. Other leniency policies also offer this type of commitment device and can be similarly abused by strategic multi-product cartels. For example, Greece has previously had a policy that firms with prior convictions for collusion may not apply for leniency.[27] In this environment, firms have an incentive to collude and get convicted in a less valuable product to protect a more valuable one. Certain jurisdictions restrict the ability of firms identified as "ringleaders" or firms having "coerced" others to participation to apply for leniency.[28] This suggests the possibility that cartels to fabricate evidence that one or perhaps all of the cartel firms are ringleaders or coercers in order to prevent leniency from being an option for those firms.

4.3 Large fine reductions contribue to detection and deterrence

Under an unlinked leniency program, deterrence is improved by increasing the fine reduction ℓ for the leniency applicant. In the case of a linked leniency program and under assumption $A1$, an increase in the fine reduction reduces the firms' payoff and increases the firms conviction probability in the first product if and only if collusive payoff in product 1 is sufficiently large relative to that in product 2. The impact on the second product is often ambiguous.

If π_1 is sufficiently small relative to π_2, then it is a dominant strategy for firms to

[27] See Wils (2008, p.138, n.139).

[28] In the United States, when the 1993 leniency rules were put in place, there were not many applications in part because, interviews with defense attorneys, firms were afraid that they would be labeled as one of the ringleaders and so reveal the cartel but not get leniency benefits. But under later revisions to the program, clarified through speeches by Department of Justice officials, in order to be denied leniency, a firm would have to be the one and only ringleader and possibly also have a role in coercing others to join. This put firms' fears to rest that they might be denied leniency based on status as a ringleader.

apply for leniency in the first product. In that case, an increase in ℓ simply increases a cartel firm's expected payoff in the event that it is prosecuted, so the increase in ℓ increases the expected payoff. However, if π_1 is large relative to π_2, then an increase in ℓ has two effects. First, as in the previous case, it increases a firm's expected payoff conditional on prosecution. Second, it increases the range of signals regarding the probability of successful prosecution in the absence of a leniency applicant (τ) for which the firms will apply for leniency, implying that the increase in ℓ increases the probability of prosecution and decreases the cartel's expected payoff. For π_1 sufficiently large relative to π_2, the second effect dominates.

Proposition 5 *Under the unlinked leniency program, an increase in the fine reduction increases deterrence. Under the linked leniency program and assumption* A1, *an increase in the fine reduction has an ambiguous effect, although it always increases deterrence for either a given $\pi_2 > 0$ and π_2/π_1 sufficiently large, or for a given $\pi_1 > 0$ and π_2/π_1 sufficiently small.*

Proof. We show in the appendix that $\frac{\partial V^U}{\partial \ell} < 0$ and that $\frac{\partial V^L}{\partial \ell} < 0$ for a given $\pi_2 > 0$ and π_2/π_1 sufficiently large, or for a given $\pi_1 > 0$ and π_2/π_1 sufficiently small.

It follows immediately from Proposition 5 that with unlinked leniency the cartel's payoff is maximized and the probability of conviction minimized when $\ell = 0$, which corresponds to the case when the leniency applicant pays the same fine as under no leniency; that is, the cartel prefers that there be no leniency program at all, while the competition authority prefers the highest possible fine reduction. This result extends to the case of linked leniency except possibly for intermediate values of π_2/π_1; however, depending upon the parameters, payoffs may be reduced by leniency for all values of π_2/π_1.[29]

These results suggest that competition authorities should consider the maximum possible fine reduction for the first leniency applicants, although there may be conditions under linked leniency in which that is no longer optimal in terms of deterrence.

[29] The numerical examples we have explored have $\frac{\partial V^L}{\partial \ell} \leq 0$ for all values of π_2/π_1.

4.4 Cartels respond to leniency with increased concealment effort

In this section, we extend the model and study the optimal choice of concealment effort by the firms. We assume that there is a preliminary round in the multi-product leniency game, round zero, in which the cartel chooses concealment effort directed at reducing the probability h with which the competition authority independently acquires evidence of collusion in a product and separately concealment effort directed at reducing the probability ρ that an internal investigation by outside counsel uncovers evidence sufficient to support a leniency application.

We assume $0 < \underline{h} < \overline{h} < 1$ and $0 < \underline{\rho} < \overline{\rho} < 1$. Let $C(h)$ be the per-firm cost of the effort needed to generate probability h, where $C(\overline{h}) = 0$, $C' < 0$, and $C'' \geq 0$ and similarly for $\hat{C}(\rho)$, the per-firm cost of the effort needed to generate probability ρ.

A leniency program introduces two effects into the cartel's concealment effort directed at reducing investigations. The first effect is that with leniency a firm may reduce its loss when convicted by the leniency benefit L_j. This effect pushes the cartel in the direction of reduced concealment. The second effect is that when the competition authority has evidence about illegal antitrust activity, the firm may apply for leniency and hence be convicted with a higher probability than when there is no leniency program. Proposition 6 shows that the second effect dominates and as a result the leniency program increases the cartel's concealment effort directed at reducing investigations. Relative to the model without leniency, the competition authority is less likely initially to receive information about illegal antitrust activity, but once the competition authority does, the cartel is convicted with higher probability in equilibrium because in some cases a cartel firm applies for leniency, providing the competition authority with the evidence required.

In addition, in the absence of a leniency program, firms have no incentive to engage in concealment effort directed at reducing the success of internal investigations, so the implementation of a leniency program also provides an incentive for increasing that type of concealment effort.

Proposition 6 *A leniency program leads to an increase in the cartel's concealment effort both directed at reducing investigations and at reducing the success of internal investigations.*

4.5 Antitrust resources are required for both investigation and prosecution

Suppose the competition authority could choose whether to direct resources towards more preliminary investigations, making it more difficult for the firms to exert concealment effort (i.e., increasing h), or towards more successful prosecutions without a leniency applicant (i.e., increasing τ_1 and/or τ_2). We consider which is more beneficial, a marginal increase in investigation or in prosecution.

Focusing on the case of a single product, we consider a small change in the probability of an investigation h and a small change $\partial\tau^E$ in the expected probability of prosecution in the absence of a leniency application due to a shift in the support of τ: $\partial\tau^E = \partial\overline{\tau} = \partial\underline{\tau}$.

Proposition 7 *If there are no investigations or no prosecution in the absence of a leniency applicant, then a leniency program offers no detection or deterrence. With a leniency program in a single product, an increase in the probability of investigation (h) and an increase in the expected probability of prosecution in the absence of a leniency applicant (τ^E) both increase detection and deterrence and are strategic complements in detection. Moreover, there exists a threshold level h^* such that an increase in τ^E has a stronger effect on detection than an increase in h if and only if $h > h^*$.*

Proof. We show in the appendix that $\frac{\partial\Psi^U}{\partial\tau^E} > 0$, $\frac{\partial\Psi^U}{\partial h} > 0$, $\frac{\partial V^U}{\partial\tau^E} < 0$, $\frac{\partial V^U}{\partial h} < 0$, and $\frac{\partial^2\Psi^U}{\partial h\partial\tau^E} > 0$.

If the competition authority eliminates resources directed at investigations, then no cartels are identified and no firms apply for leniency. If the competition authority eliminates resources directed at the prosecution of cartels under investigation but without a leniency applicant, then there is no threat to induce firms to apply for leniency and so no prosecutions. In order for a leniency program to be effective, the competition authority must maintain resources directed at both investigations and the prosecution of cartels where there is no leniency applicant.

The probability of investigations can potentially be increased through increased monitoring and reporting requirements that allow the competition authority to more easily identify anomalies. The probability of successful prosecution in the absence of a *corporate* leniency applicant can potentially be increased by encouraging whistleblowers (see Aubert, Rey, and Kovacic, 2006) or allowing *individual* leniency applicants, although one would need to consider whether the evidence provided by a whistleblower or individual applicant would be as extensive or as valuable in terms of facilitating prosecution as that of a corporate applicant.[30]

4.6 Amnesty Plus and cooperation discounts reduce the preemption effect

Under Amnesty Plus, a firm being prosecuted for collusion in one product, but not the leniency applicant, can still potentially receive treatment as if they were the leniency applicant by applying for leniency and thereby turning in a cartel in another product. According to the DoJ:

> The size of the Amnesty Plus discount depends on a number of factors, including: (1) the strength of the evidence provided by the cooperating company in the leniency product; (2) the potential significance of the violation reported in the leniency application, measured in such terms as the volume of commerce involved, the geographic scope, and the number of coconspirator companies and individuals; and (3) the likelihood the Division would have uncovered the additional violation absent the self-reporting, i.e., if there were little or no overlap in the corporate participants and/or the culpable executives involved in the original cartel under investigation and the Amnesty Plus matter, then the credit for the disclosure would be greater. Of these three factors, the first two are given the most weight.[31]

Under Amnesty Plus, if firms collude in only one product the results are the same as for unlinked leniency. We model the policy as implying that if the same two firms collude in two products, then Amnesty Plus does not apply, so the results are the same as for linked leniency. But suppose that firm 1 and firm 2 collude in product 1, but firm 1 colludes in product B_1 with a firm other than firm 2 and firm 2 colludes in product B_2 with a firm other than firm 1. We can then consider the effect of Amnesty Plus on incentives to apply for leniency in product 1.

[30] In our model, we focus on responses by firms to an investigation (type B leniency). Based on interviews with defense attorneys, in the United States, individual leniency does not come up very often.

[31] The U.S. Department of Justice's "Frequently Asked Questions Regarding the Antitrust Division's Leniency Program and Model Leniency Letters" (2008, p.9) (available at http://www.justice.gov/atr/public/criminal/239583.htm, accessed October 23, 2012).

For simplicity, we assume that the payoffs in products B_1 and B_2 are small relative to the payoffs and penalties for collusion in product 1 and focus only on the incentives generated by payoffs in product 1.

The game is as follows:

1. In the first round, the firms play the *stand-alone leniency game* in product 1.

2. In the second round, if $v_1 = 0$ or if $v_1 = 1$ and neither firm received leniency, then the game ends, but if $v_1 = 1$ and firm i received leniency then the following occurs:

   (a) Firm i' learns whether it has sufficient evidence to support a leniency application in product $B_{i'}$. If so, it chooses whether to invoke Amnesty Plus or not.

   (b) If firm i' cannot or chooses not to invoke Amnesty Plus, the game ends with firm i' receiving payoff zero in product 1.

   (c) If firm i' invokes Amnesty Plus, it receives the leniency payoff in product 1 (and in product $B_{i'}$).

Once one firm has received leniency in the first product, the other firm faces a payoff of L_1 if it invokes Amnesty Plus and a payoff of zero if it does not. Thus, given sufficient evidence, firm 2 chooses Amnesty Plus. To further simplify calculations for this case, assume that the firms are always able to produce sufficient evidence to support a leniency application in the B products, which, for example, would be the case if the firms had deliberately established collusion in those products for the purposes of supporting a Amnesty Plus application.

In this model, from the perspective of the first round, if firm 1 has sufficient evidence to apply for leniency, its expected payoffs are:

	L	N
L	$(1-\frac{\rho}{2})L_1 + \frac{\rho}{2}L_1 = L_1$	L_1
N	$(1-\rho)(1-\tau_1)\pi_1 + \rho L_1$	$(1-\tau_1)\pi_1$

To understand these payoffs, note that if firm 1 chooses L and firm 2 uses the strategy of choosing L when feasible (probability ρ), then with probability $1-\frac{1}{2}\rho$, firm 1 receives leniency. In that case, firm 1 has payoff L_1. With probability $\frac{1}{2}\rho$, firm 1 does not receive leniency, but firm 2 does. Then firm 1 invokes Amnesty Plus with probability 1, in which case its payoff is L_1. If firm 1 chooses N and firm 2 uses the strategy of choosing L when feasible (probability ρ), then with probability ρ, firm 2 receives leniency and firm 1 invokes Amnesty Plus.

As you can see, comparing these payoffs to those for the unlinked leniency game, the payoff in the upper left cell is increased by $\frac{\rho}{2}L_1$ (firm 1 can still receive leniency even when the other firms is selected as the leniency recipient), and the payoff in the lower right cell is increased by ρL_1 (firm 1 can receive leniency when firm 2 successfully applies for leniency). In this game, if $\tau_1 > 1-\ell$, then (L, L) is the unique Nash equilibrium and if $\tau_1 < 1 - \ell$, then (N, N) is the unique Nash equilibrium. In equilibrium, each firm applies for leniency if evidence permits for all $\theta_{1j} > 1 - \ell$, but does not for all $\theta_{1j} < 1 - \ell$. Recall that τ^* is the relevant threshold for the unlinked leniency game, and since $1 - \ell > \tau^*$, it follows that the probability of a leniency application and hence the probability of successful prosecution is reduced by the Amnesty Plus program.

The negative effect of Amnesty Plus on detection and deterrence occurs because Amnesty Plus reduces the preemption effect. A firm has less incentive to apply for leniency if it can obtain a similar fine reduction through Amnesty Plus in the event that its co-conspirator does apply for leniency. A similar reduction in the preemption effect occurs when the competition authority offers fine discounts for cooperating firms other than the first firm to apply for leniency.

4.7 Settlement negotiation can reduce deterrence

In many jurisdictions, firms being prosecuted for collusion may negotiate a settlement with the government. There appears to be some flexibility for cartels to negotiate settlement terms that favor them in terms of limiting future penalties, for example from civil litigation, in exchange for concessions that fit current priorities of the competition authority, which may include the amount of criminal fines, the number of individuals receiving prison terms, or the total length of prison terms.[32]

Limited criminal pleas, for example in terms of plea length, customers affected, or geography, can handicap the ability of civil litigants to pursue damages and hence

[32] Policies vary in terms of the flexibility for settlement terms. For example, the Australian DPP's Prosecution Policy states that the charges should bear a reasonable relationship to the nature of the criminal conduct of the accused.

reduce deterrence. For example, in the *Vitamins* conspiracy, the firms pled guilty to a price fixing conspiracy with a start date of 1990, when it is possible that the conspiracy began as early as 1985.[33] In the DRAM conspiracy, firms pled guilty to a conspiracy that affected only "certain OEMs of personal computers and servers," when the conspiracy may have affected prices more generally. In the EC decision in *Candle Waxes,* the decision limits the effects in slack wax only to Germany.

5 Conclusion

The U.S. leniency program has been in place in roughly its current form since 1993. The past approximately twenty years have given colluding firms an opportunity to adjust their behavior to account for the presence of the leniency program. We must expect colluding firms to optimize given the existence of leniency. Our results point to the possibility that colluding firms might turn to their advantage an enforcement approach that links the availability of leniency across products for firms engaged in collusion in multiple products. Our results point to the possibility that firms might create sacrificial cartels in minor products in order to protect cartels in more valuable products from the threat that a cartel member might apply for leniency.

A number of policy implications follow from the results of this paper. Competition authorities should (1) use particular care when linking leniency procedures for firms participating in cartels in multiple products; (2) avoid policies that offer avenues for firms to commit themselves not to apply for leniency; (3) maintain resources to investigate and uncover cartels as well as resources to prosecute cartels even in the absence of a leniency applicant; (4) ensure that policies that reduce the preemption effect, such as cooperation discounts, generate counterbalancing benefits; (5) align incentives so that settlement negotiations accurately reflect the evidence in the case; and (6) generally consider how clever cartels will respond the programs put in place.

[33] See Marshall, Marx, and Raiff (2008) for economic evidence supporting the conclusion that the conspiracy began in 1985.

A Omitted proofs

Proof of Lemma 1. Using the definitions of Ψ^U and Ψ^F,

$$\begin{aligned}
\Psi^U - \Psi^F &= h\left[1-(1-\rho)^2(1-\tau^E) - \rho\,(2-\rho)\int_{\underline{\tau}}^{\tau^*}\frac{1-\tau}{\overline{\tau}-\underline{\tau}}d\tau\right] - h\tau^E \\
&= h\rho\,(2-\rho)\left[1-\tau^E - \int_{\underline{\tau}}^{\tau^*}\frac{1-\tau}{\overline{\tau}-\underline{\tau}}d\tau\right] \\
&> 0.
\end{aligned}$$

Using (4), we have:

$$\begin{aligned}
V^U - V^F &= 1-\Psi^U + \frac{1}{2}h\rho\,(2-\rho)\int_{\tau^*}^{\overline{\tau}}\frac{\ell}{\overline{\tau}-\underline{\tau}}d\tau - \left(1-\Psi^F\right) \qquad (7)\\
&= \Psi^F - \Psi^U + \frac{1}{2}h\rho\,(2-\rho)\int_{\tau^*}^{\overline{\tau}}\frac{\ell}{\overline{\tau}-\underline{\tau}}d\tau \\
&= -h\rho\,(2-\rho)\left[1-\tau^E - \int_{\underline{\tau}}^{\tau^*}\frac{1-\tau}{\overline{\tau}-\underline{\tau}}d\tau\right] + \frac{1}{2}h\rho\,(2-\rho)\int_{\tau^*}^{\overline{\tau}}\frac{\ell}{\overline{\tau}-\underline{\tau}}d\tau \\
&= h\rho\,(2-\rho)\,\frac{1}{2}\left(\int_{\tau^*}^{\overline{\tau}}\frac{\ell-2(1-\tau)}{\overline{\tau}-\underline{\tau}}d\tau\right) \\
&> 0,
\end{aligned}$$

where the inequality uses

$$\begin{aligned}
\int_{\tau^*}^{\overline{\tau}}\left(\ell-2\,(1-\tau)\right)d\tau &= \left(\overline{\tau}-\tau^*\right)\left(\ell-2+\overline{\tau}+\tau^*\right) \\
&= \left(\overline{\tau}-\tau^*\right)\left(\ell-1+\overline{\tau}-\frac{4-\rho}{4-2\rho}\ell\right) \\
&< 0.
\end{aligned}$$

Q.E.D.

Proof of Proposition 4. Under assumption $A1$,

$$\Psi_1^L - \Psi^U = h\rho\,(2-\rho)\int_{\tau^{**}}^{\tau^*}\frac{1-\tau}{\overline{\tau}-\underline{\tau}}d\tau > 0.$$

Using $\Psi_2^L = \Psi_1^L \Psi^F + (1-\Psi_1^L)\Psi^U$ and $\Psi^F < \Psi^U$, it follows that $\Psi_2^L < \Psi^U$. In addition,

$$\begin{aligned} V^U - V_1^L &= 1 - \Psi^U + \frac{1}{2} h\rho (2-\rho) \int_{\tau^*}^{\overline{\tau}} \frac{\ell}{\overline{\tau} - \underline{\tau}} d\tau \\ &\quad - \left(1 - \Psi^U + \frac{1}{2} h\rho (2-\rho) \int_{\tau^*}^{\overline{\tau}} \frac{\ell}{\overline{\tau} - \underline{\tau}} d\tau\right) \\ &= \Psi_1^L - \Psi^U - h\rho (2-\rho) \frac{1}{2} \int_{\tau^{**}}^{\tau^*} \frac{\ell}{\overline{\tau} - \underline{\tau}} d\tau \\ &= h\rho (2-\rho) \frac{1}{2} \int_{\tau^{**}}^{\tau^*} \frac{2(1-\tau) - \ell}{\overline{\tau} - \underline{\tau}} d\tau > 0, \end{aligned}$$

where the inequality follows from

$$\int_{\tau^{**}}^{\tau^*} (2(1-\tau) - \ell)\, d\tau > \int_{\tau^{**}}^{\tau^*} \left(\frac{4-\rho}{2-\rho}\ell - \ell\right) d\tau > 0.$$

Q.E.D.

Proof of Proposition 5. By (1),

$$\begin{aligned} \frac{\partial \Psi^U}{\partial \ell} &= -h\rho (2-\rho) \frac{1-\tau^*}{\overline{\tau} - \underline{\tau}} \frac{\partial \tau^*}{\partial \ell} \\ &= h\rho (2-\rho) \frac{1-\tau^*}{\overline{\tau} - \underline{\tau}} \frac{4-\rho}{4-2\rho} > 0. \end{aligned} \tag{8}$$

Using the definition of V^U,

$$\begin{aligned} \frac{\partial \sum_{j=1}^2 V^U}{\partial \ell} &= \frac{\partial}{\partial \ell} 2 \left(1 - \Psi^U + \frac{1}{2} h\rho (2-\rho) \int_{\tau^*}^{\overline{\tau}} \frac{\ell}{\overline{\tau} - \underline{\tau}} d\tau\right) \\ &= 2\left(-\frac{\partial \Psi^U}{\partial \ell} + \frac{1}{2} h\rho (2-\rho) \frac{\overline{\tau} - \tau^*}{\overline{\tau} - \underline{\tau}} - \frac{1}{2} h\rho (2-\rho)\, \ell \frac{\frac{\partial \tau^*}{\partial \ell}}{\overline{\tau} - \underline{\tau}}\right) \\ &= 2\left(h\rho (2-\rho) \frac{1-\tau^*}{\overline{\tau} - \underline{\tau}} \frac{\partial \tau^*}{\partial \ell} + \frac{1}{2} h\rho (2-\rho) \frac{\overline{\tau} - \tau^*}{\overline{\tau} - \underline{\tau}} - \frac{1}{2} h\rho (2-\rho) \frac{\ell}{\overline{\tau} - \underline{\tau}} \frac{\partial \tau^*}{\partial \ell}\right) \\ &= h\rho (2-\rho) \frac{1}{\overline{\tau} - \underline{\tau}} \left(\overline{\tau} - \tau^* - \frac{\partial \tau^*}{\partial \ell} (\ell - 2(1-\tau^*))\right), \end{aligned}$$

which, using $\frac{\partial \tau^*}{\partial \ell} = -\frac{4-\rho}{4-2\rho}$, has sign equal to the sign of

$$\begin{aligned}\overline{\tau} - \tau^* + \frac{4-\rho}{4-2\rho}\left(\ell - 2\left(1-\tau^*\right)\right) &= \overline{\tau} - 1 + \frac{4-\rho}{4-2\rho}\ell + \frac{4-\rho}{4-2\rho}\left(\ell - 2\left(1-\tau^*\right)\right) \\ &= \overline{\tau} - 1 - \frac{4-\rho}{4-2\rho}\frac{2\rho}{4-2\rho}\ell \\ &< 0,\end{aligned}$$

where the inequality follows from $\overline{\tau} < 1$ and $\rho \in (0,1)$.

We now state and prove the following lemma.

Lemma 2 *Under assumption A1 and a linked leniency program, there are two cases: (i) if* $\frac{\pi_2}{\pi_1} > \frac{1}{V^F - V^U}$*, then* $\frac{\partial V_1^L}{\partial \ell} > 0$*, and (ii) if* $\frac{\pi_2}{\pi_1} < \frac{1}{V^F - V^U}$*, then* $\frac{\partial V_1^L}{\partial \ell} < 0$.

Proof of Lemma 2. (i) If $\frac{\pi_2}{\pi_1} > \frac{1}{V^F - V^U}$, then τ^{**} does not depend on ℓ, so it is clear from the definitions of V_1^L and Ψ_1^L that $\frac{\partial V_1^L}{\partial \ell} > 0$. (ii) If $\frac{\pi_2}{\pi_1} < \frac{1}{V^F - V^U}$, then, letting $Q \equiv 1 - \left(V^F - V^U\right)\frac{\pi_2}{\pi_1} \in (0,1)$, if τ^{**} is interior between $\underline{\tau}$ and $\overline{\tau}$, then

$$\frac{\partial \tau^{**}}{\partial \ell} = -\frac{4-\rho}{4-2\rho}\frac{Q - \ell\frac{\partial V^U}{\partial \ell}\frac{\pi_2}{\pi_1}}{Q^2} < 0,$$

where the inequality follows from

$$Q - \ell\frac{\partial V^U}{\partial \ell}\frac{\pi_2}{\pi_1} > 0,$$

where this inequality uses the supposition that $\frac{\pi_2}{\pi_1} < \frac{1}{V^F - V^U}$, which implies $Q \in (0,1)$ and the fact that $\frac{\partial V^U}{\partial \ell} < 0$. Thus, $\frac{\partial \tau^{**}}{\partial \ell} \leq 0$ and it is clear the definition of Ψ_1^L, that $\frac{\partial \Psi_1^L}{\partial \ell} \geq 0$, and

$$\begin{aligned}\frac{\partial V_1^L}{\partial \ell} &= -\frac{\partial \Psi_1^L}{\partial \ell} + \frac{1}{2}h\rho\left(2-\rho\right)\int_{\tau^{**}}^{\overline{\tau}} \frac{1}{\overline{\tau} - \underline{\tau}} d\tau - \frac{1}{2}h\rho\left(2-\rho\right)\frac{\ell}{\overline{\tau} - \underline{\tau}}\frac{\partial \tau^{**}}{\partial \ell} \\ &= h\rho(2-\rho)\frac{1}{2}\frac{1}{\overline{\tau} - \underline{\tau}}\left(\overline{\tau} - \tau^{**} - \frac{\partial \tau^{**}}{\partial \ell}\left(\ell - 2(1-\tau^{**})\right)\right),\end{aligned}$$

which has the sign of

$$\overline{\tau} - \tau^{**} - \ell\frac{\partial \tau^{**}}{\partial \ell} + 2\left(1-\tau^{**}\right)\frac{\partial \tau^{**}}{\partial \ell}. \tag{9}$$

To evaluate this, let $Z \equiv -\frac{\ell}{1-\tau^{**}} \frac{\partial \tau^{**}}{\partial \ell} \geq 0$ and note that

$$\begin{aligned}
1 + \frac{4-\rho}{4-2\rho}\frac{Q-2}{Q}Z &= 1 - \frac{4-\rho}{4-2\rho}\frac{Q-2}{Q}\frac{\ell}{1-\tau^{**}}\frac{\partial \tau^{**}}{\partial \ell} \\
&= 1 - (Q-2)\frac{\partial \tau^{**}}{\partial \ell} \\
&= 1 + (Q-2)\frac{4-\rho}{4-2\rho}\frac{Q - \ell \frac{\partial V^U}{\partial \ell}\frac{\pi_2}{\pi_1}}{Q^2} \\
&< 1 + (Q-2)\frac{4-\rho}{4-2\rho}\frac{Q}{Q^2} \\
&< 0,
\end{aligned} \tag{10}$$

where the first inequality uses $\frac{\partial V^U}{\partial \ell} < 0$ and the second uses $Q \in (0,1)$. Now returning to (9), we have

$$\begin{aligned}
& \overline{\tau} - \tau^{**} - \ell\frac{\partial \tau^{**}}{\partial \ell} + 2\left(1-\tau^{**}\right)\frac{\partial \tau^{**}}{\partial \ell} \\
< \; & \left(1-\tau^{**}\right)\left(1 + 2\frac{\partial \tau^{**}}{\partial \ell}\right) - \ell\frac{\partial \tau^{**}}{\partial \ell} \\
= \; & \left(1-\tau^{**}\right)\left(1 + 2\frac{\partial \tau^{**}}{\partial \ell} - \frac{\ell}{1-\tau^{**}}\frac{\partial \tau^{**}}{\partial \ell}\right) \\
= \; & \left(1-\tau^{**}\right)\left(1 - 2\frac{1-\tau^{**}}{\ell}Z + Z\right) \\
= \; & \left(1-\tau^{**}\right)\left(1 - 2\frac{4-\rho}{4-2\rho}\frac{Z}{Q} + Z\right) \\
= \; & \left(1-\tau^{**}\right)\left(1 + \frac{\left(4-2\rho\right)Q - 2(4-\rho)}{\left(4-2\rho\right)Q}Z\right) \\
< \; & \left(1-\tau^{**}\right)\left(1 + \frac{\left(4-\rho\right)Q - 2(4-\rho)}{\left(4-2\rho\right)Q}Z\right) \\
= \; & \left(1-\tau^{**}\right)\left(1 + \frac{4-\rho}{4-2\rho}\frac{Q-2}{Q}Z\right) \\
< \; & 0,
\end{aligned}$$

where the first inequality follows from $\overline{\tau} < 1$, the second inequality substitutes $4-\rho$ for $4-2\rho$, and the third inequality follows from (10). Thus, $\frac{\partial V_1^L}{\partial \ell} < 0$. Q.E.D.

(i) If $\frac{\pi_2}{\pi_1} > \frac{1}{V^F - V^U}$, then using the lemma above we have

$$\frac{\partial V^L}{\partial \ell} = \underbrace{\frac{\partial V_1^L}{\partial \ell}\pi_1}_{+} + \underbrace{\frac{\partial \Psi_1^L}{\partial \ell}\left(V^F - V^U\right)\pi_2}_{0} + \underbrace{\Psi_1^L \frac{\partial V^F}{\partial \ell}\pi_2}_{0} + \underbrace{(1-\Psi_1^L)\frac{\partial V^U}{\partial \ell}\pi_2}_{-},$$

where the signs of each term follow from Lemma 2, (1) and (3). In addition, if we fix $\pi_2 > 0$ and let $\pi_1 \downarrow 0$, $\frac{\partial V^U}{\partial \ell}$ stays bounded away from zero, while $\frac{\partial V_1^L}{\partial \ell} \downarrow 0$.

(ii) If $\frac{\pi_2}{\pi_1} < \frac{1}{V^F - V^U}$, then we have

$$\frac{\partial V^L}{\partial \ell} = \underbrace{\frac{\partial V_1^L}{\partial \ell}\pi_1}_{-} + \underbrace{\frac{\partial \Psi_1^L}{\partial \ell}\left(V^F - V^U\right)\pi_2}_{+} + \underbrace{\Psi_1^L \frac{\partial V^F}{\partial \ell}\pi_2}_{0} + \underbrace{(1-\Psi_1^L)\frac{\partial V^U}{\partial \ell}\pi_2}_{-},$$

where the signs of each term again follow from Lemma 2, (1) and (3). If we fix $\pi_1 > 0$ and let $\pi_2 \downarrow 0$, $V^F - V^U \downarrow 0$, $\frac{\partial V^U}{\partial \ell} \uparrow 0$, while $\frac{\partial V_1^L}{\partial \ell}$ stays bounded away from zero. Q.E.D.

Proof of Proposition 6. Clearly, without an antitrust leniency program, the cartel has no incentive to expend effort to reduce ρ, so $\rho^N = \overline{\rho} \geq \rho^U$.

In the absence of a leniency program, the cartel is convicted in each product with probability $\Psi^N = h^N \tau^E$. A cartel firm's expected payoff without a leniency program is

$$\sum_{j=1}^{2} V^N(h^N)\pi_j - C(h^N) = \sum_{j=1}^{2} \left(1 - h^N \tau^E\right)\pi_j - C(h^N).$$

Thus, in the absence of an antitrust leniency program, the cartel chooses concealment effort such that the probability h^N that the competition authority receives information about illegal antitrust activity satisfies:

$$C'\left(h^N\right) = -\tau^E\left(\pi_1 + \pi_2\right). \tag{11}$$

With an unlinked leniency program, the expected payoff of each firm is $\sum_{j=1}^{2} V^U(h)\pi_j -$

$C(h)$. The first order condition of the cartel's maximization problem gives:

$$\begin{aligned} C'(h^U) &= \frac{\partial V^U(h^U)}{\partial h}(\pi_1+\pi_2) \\ &= \left(-\tau^E + \rho\,(2-\rho)\,\frac{1}{2}\int_{\tau^*}^{\overline{\tau}} \frac{\ell - 2(1-\tau)}{\overline{\tau}-\underline{\tau}} d\tau\right)(\pi_1+\pi_2). \end{aligned} \tag{12}$$

If there is a single product and a leniency program is in place, then the cartel chooses concealment effort such that $C'\left(h^U\right)$ satisfies (12). Since C is a convex function, comparing the first order conditions for the choice of h with and without a leniency program (i.e., comparing (12) with (11)), it is immediate that $h^N > h^U$ if and only if

$$\int_{\tau^*}^{\overline{\tau}} \frac{\ell - 2(1-\tau)}{\overline{\tau}-\underline{\tau}} d\tau < 0,$$

which can be rewritten as

$$\begin{aligned} \int_{\tau^*}^{\overline{\tau}} \frac{\ell - 2(1-\tau)}{\overline{\tau}-\underline{\tau}} d\tau &= \frac{\overline{\tau}-\tau^*}{\overline{\tau}-\underline{\tau}}\left(\ell - 2 + \overline{\tau} + \tau^*\right) \\ &= \frac{\overline{\tau}-\tau^*}{\overline{\tau}-\underline{\tau}}\left(\ell - 2 + \overline{\tau} + 1 - \frac{4-\rho}{4-2\rho}\ell\right) \\ &= \frac{\overline{\tau}-\tau^*}{\overline{\tau}-\underline{\tau}}\left(-\ell\frac{\rho}{4-2\rho} - 1 + \overline{\tau}\right) \\ &< \frac{\overline{\tau}-\tau^*}{\overline{\tau}-\underline{\tau}}\left(-\left(1-\overline{\tau}\right)\frac{\rho}{4-2\rho} - 1 + \overline{\tau}\right) \\ &= \frac{\overline{\tau}-\tau^*}{\overline{\tau}-\underline{\tau}}\left(1-\overline{\tau}\right)\left(-\frac{\rho}{4-2\rho} - 1\right) \\ &< 0, \end{aligned}$$

where the inequality uses assumption $A0$, which implies $1-\overline{\tau} < \ell$.

Note that

$$\begin{aligned} C'(h^L) - C'(h^U) &= \left(V^U(h^L) - V^U(h^U)\right)\frac{1}{h}(\pi_1+\pi_2) + \left(\frac{\partial V_1^L(h^L)}{\partial h} - \frac{\partial V^U(h^L)}{\partial h}\right)\pi_1 \\ &\quad + \left(\frac{\partial \Psi_1^L(h^L)}{\partial h} + \frac{1}{h}\Psi_1^L(h^L)\right)\left(V^F(h^L) - V^U(h^L)\right)\pi_2. \end{aligned} \tag{13}$$

Taking the limit as $\pi_1 \to 0$, we have

$$\begin{aligned}\lim_{\pi_1 \to 0}\left(C'(h^L) - C'(h^U)\right) &= \left(V^U(h^L) - V^U(h^U)\right)\frac{1}{h}\pi_2 \\ &+ \left(\frac{\partial \Psi_1^L(h^L)}{\partial h} + \frac{1}{h}\Psi_1^L(h^L)\right)\left(V^F(h^L) - V^U(h^L)\right)\pi_2,\end{aligned} \quad (14)$$

which is positive for $h^L < h^U$ (since $\frac{\partial \Psi_1^L(h^L)}{\partial h}$, $\Psi_1^L(h^L)$, and $V^F(h^L) - V^U(h^L)$ are positive. Taking the limit as $\pi_2 \to 0$, we have

$$\lim_{\pi_2 \to 0}\left(C'(h^L) - C'(h^U)\right) = \left(V^U(h^L) - V^U(h^U)\right)\frac{1}{h}\pi_1 + \left(\frac{\partial V_1^L(h^L)}{\partial h} - \frac{\partial V^U(h^L)}{\partial h}\right)\pi_1,$$

which is negative, which implies the second term on the right side above is negative, if $h^L > h^U$. It follows that $h^L > h^U$ for a given $\pi_2 > 0$ and π_2/π_1 sufficiently large and $h^L < h^U$ for a given $\pi_1 > 0$ and π_2/π_1 sufficiently small. Q.E.D.

Proof of Proposition 7. We have

$$\frac{\partial \Psi^U}{\partial \tau^E} = h(1-\rho)^2 + h\rho\,(2-\rho)\,\frac{1-\underline{\tau}}{\overline{\tau}-\underline{\tau}} > 0$$

and

$$\frac{\partial \Psi^U}{\partial h} = 1 - (1-\rho)^2(1-\tau^E) - \rho\,(2-\rho)\int_{\underline{\tau}}^{\tau^*}\frac{1-\tau}{\overline{\tau}-\underline{\tau}}d\tau > 0.$$

It follows that $\frac{\partial^2 \Psi^U}{\partial h \partial \tau^E} > 0$ and that $\frac{\partial \Psi^U}{\partial \tau^E} > \frac{\partial \Psi^U}{\partial h}$ if and only if

$$h > h^* \equiv \frac{1 - (1-\rho)^2(1-\tau^E) - \rho\,(2-\rho)\int_{\underline{\tau}}^{\tau^*}\frac{1-\tau}{\overline{\tau}-\underline{\tau}}d\tau}{(1-\rho)^2 + \rho\,(2-\rho)\frac{1-\underline{\tau}}{\overline{\tau}-\underline{\tau}}}.$$

Moreover, we have

$$\begin{aligned}\frac{\partial V^U}{\partial \tau^E} &= -\frac{\partial \Psi^U}{\partial \tau^E} + \frac{1}{2}h\rho\,(2-\rho)\,\frac{\ell}{\overline{\tau}-\underline{\tau}} \\ &= -h(1-\rho)^2 - h\rho\,(2-\rho)\,\frac{1-\underline{\tau}}{\overline{\tau}-\underline{\tau}} + \frac{1}{2}h\rho\,(2-\rho)\,\frac{\ell}{\overline{\tau}-\underline{\tau}} \\ &= h\left(-(1-\rho)^2 + \frac{\rho\,(2-\rho)}{\overline{\tau}-\underline{\tau}}\frac{1}{2}\left(\ell - 2(1-\underline{\tau})\right)\right) \\ &< 0,\end{aligned}$$

where the inequality uses assumption $A0$, which implies $\ell - 2(1-\underline{\tau}) < 0$, and

$$\begin{aligned}
\frac{\partial V^U}{\partial h} &= -\frac{\partial \Psi^U}{\partial h} + \frac{1}{2}\rho\,(2-\rho)\int_{\tau^*}^{\overline{\tau}} \frac{\ell}{\overline{\tau}-\underline{\tau}}d\tau \\
&= -1 + (1-\rho)^2(1-\tau^E) + \rho\,(2-\rho)\int_{\underline{\tau}}^{\tau^*} \frac{1-\tau}{\overline{\tau}-\underline{\tau}}d\tau + \frac{1}{2}\rho\,(2-\rho)\int_{\tau^*}^{\overline{\tau}} \frac{\ell}{\overline{\tau}-\underline{\tau}}d\tau \\
&= -1 + (1-\rho)^2(1-\tau^E) + \rho\,(2-\rho)\left(\int_{\underline{\tau}}^{\overline{\tau}} \frac{1-\tau}{\overline{\tau}-\underline{\tau}}d\tau - \int_{\tau^*}^{\overline{\tau}} \frac{1-\tau}{\overline{\tau}-\underline{\tau}}d\tau\right) \\
&\quad + \frac{1}{2}\rho\,(2-\rho)\int_{\tau^*}^{\overline{\tau}} \frac{\ell}{\overline{\tau}-\underline{\tau}}d\tau \\
&= -1 + (1-\rho)^2(1-\tau^E) + \rho\,(2-\rho)\,(1-\tau^E) - \rho\,(2-\rho)\int_{\tau^*}^{\overline{\tau}} \frac{1-\tau}{\overline{\tau}-\underline{\tau}}d\tau \\
&\quad + \frac{1}{2}\rho\,(2-\rho)\int_{\tau^*}^{\overline{\tau}} \frac{\ell}{\overline{\tau}-\underline{\tau}}d\tau \\
&= -\tau^E - \rho\,(2-\rho)\int_{\tau^*}^{\overline{\tau}} \frac{1-\tau}{\overline{\tau}-\underline{\tau}}d\tau + \frac{1}{2}\rho\,(2-\rho)\int_{\tau^*}^{\overline{\tau}} \frac{\ell}{\overline{\tau}-\underline{\tau}}d\tau \\
&= -\tau^E + \rho\,(2-\rho)\,\frac{1}{2}\int_{\tau^*}^{\overline{\tau}} \frac{\ell - 2(1-\tau)}{\overline{\tau}-\underline{\tau}}d\tau \\
&< -\tau^E + \rho\,(2-\rho)\,\frac{1}{2}\int_{\tau^*}^{\overline{\tau}} \frac{\ell - 2(1-\overline{\tau})}{\overline{\tau}-\underline{\tau}}d\tau \\
&= -\tau^E + \rho\,(2-\rho)\,\frac{1}{2}\frac{\ell - 2(1-\overline{\tau})}{\overline{\tau}-\underline{\tau}}(\overline{\tau}-\tau^*) \\
&< -\tau^E + \rho\,(2-\rho)\,\frac{1}{2}\frac{1-\overline{\tau} - 2(1-\overline{\tau})}{\overline{\tau}-\underline{\tau}}(\overline{\tau}-\tau^*) \\
&= -\tau^E - \rho\,(2-\rho)\,\frac{1}{2}\frac{1-\overline{\tau}}{\overline{\tau}-\underline{\tau}}(\overline{\tau}-\tau^*) \\
&< 0,
\end{aligned}$$

where the first inequality substitutes for the variable of integration and the second inequality uses assumption $A0$, which implies that $1-\overline{\tau} < \ell$. Q.E.D.

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