What Doesn't Kill us Makes us Stronger: An Analysis of Corporate Leniency Policy.

Christopher J. Ellis and Wesley W. Wilson*.

*Department of Economics, University of Oregon,
Eugene OR 97405, USA.

May 2001.
(Very Preliminary First Draft: Please do not quote)

Abstract

We develop a simple model of cartel behavior under conditions of Bertrand competition with differentiated products. This model is then used to analyse the effects of "Leniency Policy" on the cartel. We find that in some market situations introducing Leniency Policy causes the cartel to cease to be viable and competition results. However, in other cases the policy only serves to raise cartel prices and profits. This latter result seems to occur in precisely those circumstances where cartels are most damaging.

Keywords: Leniency Policy, Cartels, Competition Policy, Price Fixing.

JEL classification: L4, D43, K21.

1 Introduction

Over the past 10 years several jurisdictions including the US, Canada, UK, New Zealand, Australia, and the European Union have either introduced or revised their antitrust policies. A primary objective of these policy changes has been the prevention of the abuse of market power by cartels. In each case one of the policy tools adopted involves "Leniency" whereby a cartel member which reports anti-competitive behavior to the appropriate administrative body is given either partial or total leniency from any subsequent penalties. On the surface we might expect the introduction of leniency policies to spark a round of cartel breakups, as firms attempt to report on others before they themselves are reported on. Indeed there is evidence that there has been a surge in such reporting. Since the introduction of a policy of automatic leniency for firms that self-report antitrust violations in 1993 the annual fines paid to the US Department of Justice Antitrust Division have risen from $23 million in 1993 to $1.1 billion in 1999. Further, the DOJ has successfully prosecuted a large number of antitrust cases, including several extremely large international price fixing cartels such as the now infamous Lysine, Vitamins, and Graphite Electrodes cases[1].

While the DOJ and its foreign counterparts have recently enjoyed great success in their cartel busting activities, much of which has been publicly attributed to the introduction of corporate leniency policy, it is not immediately obvious why this success has occurred[2]. The casual "I'll report you before you report me" argument does not seem very persuasive[3]. Why should cartels that enjoyed supernormal profits before the introduction of the policy decide to abandon this

[1] Examples of punishments enacted under the Sherman act in these cases include

Firm	Cartel	Year	Fine $mil.	Country.
F. Hoffmann-La Roche	Vitamins	99	500	Switzerland
BASF AG	Vitamins	99	225	Germany
Takeda Chemicals	Vitamins	99	72	Japan
Eisai Co.	Vitamins	99	40	Japan
Daiichi Pharmaceuticals	Vitamins	99	25	Japan
Lonza AG	Vitamins	98	10.5	Switzerland
Archer Daniels Midland	Lysine	97	100	U.S.
Ajinomoto Co	Lysine	96	10	Japan
Kyowa Hakko Kogyo	Lysine	96	10	Japan
SGL Carbon AG	Graphite Electrodes	99	135	Germany
UCAR Int'l	Graphite Electrodes	98	110	U.S.
Showa Denko Carbon	Graphite Electrodes	98	32.5	Japan

Source: U.S. Department of Justice, Antitrust Division, Office of Criminal Enforcement, Annual Report. Available at *http://www.usdoj.gov/atr/public/4523e.htm*

[2] Gary R. Spratling, Deputy Assistant Attorney General for Antitrust, U.S. Department of Justice has claimed that "today the Amnesty (Leniency) Progam is the Division's most effective generator of large cases."

Source; Speach before the Bar Assoc. of D.C.'s 35th Annual Symposium on Associations and Antitrust, (Feb. 16, 1999).

[3] Motta and Polo [6] have made a persuasive case for the efficacy of leniency policies *once an antitrust investigation is underway*, but cannot explain the policies apparent success in stimulating self-reporting by violators.

lucrative arrangement merely on the basis of mutual distrust? Each cartel member makes positive profits by remaining in a cartel, and only avoids losses by reporting it's activities to the authorities. Clearly if a firm believes it's cartel associates are about to report it to the authorities it will attempt to act first, but why should such expectations arise?

In this paper we argue that the observed success of leniency policy may be attributable to more immediately tangible effects. The punishments most countries impose on antitrust offenders tend to have asymmetric effects on their costs and revenues, potentially significantly changing their incentives and market behavior. In certain circumstances reporting antitrust abuses changes the market equilibrium such that, for some time period, the squealers profits rise and the other firms profits fall. This provides a simple direct explanation of the success of leniency policy. However, our analysis also shows that leniency policy is a double edged sword, in cases where cartel break up does not take place the abuse of market power typically becomes more severe.

We base our arguments on an analysis of cartel behavior under Bertrand competition with differentiated products. What we are able to show is that if the cartel is maintained by a trigger strategy of reversion to Nash behavior, then the introduction of a leniency policy is "more likely" to eliminate the cartel; (1) the less concentrated is the industry; (2) the larger is the penalty imposed by the anti-trust authority; (3) the more the cartel members discount the future. However, when the introduction of the policy does not eliminate the cartel then it changes the payoffs associated with both defection and those associated with the punishment strategy in such a way that the abuses of cartel power typically increase, i.e. the cartel price and level of supernormal profits rise. Furthermore, leniency policy, in combination with antitrust violation penalties common to many countries, make it possible for the trigger strategies assumed responsible for the maintenance of cartel equilibria to be weakly renegotiation proof.

The rest of our paper is organized as follows. In section 2 we introduce a simple model of cartel formation under Bertrand competition. In section 3 we add antitrust and leniency policies to the simple model of section 2. We analyses the incentives for a cartel member to squeal on its fellows. In section 4 we consider the possibility that squealing may be part of the cartel's enforcement mechanism. Finally in section 5 we consider some of the implications and limitations of our analysis and suggest some further questions for study.

2 Base Model: No Leniency Policy.

To act as a benchmark we initially introduce a model in which there is no effective antitrust policy of any kind. If firms in an industry wish to form cartels they simply do so. We assume the industry consists of h firms which produce similar but differentiated products under conditions of Bertrand competition.

The demand faced by any firm i is written in the form

$$q_i = q_i(p_1, ..., p_h) = A - p_i + \frac{1}{h-1}\sum_{j \neq i} p_j. \tag{1}$$

Further, each firm is assumed to face an identical quadratic cost function

$$c_i = c_i(q_i) = q_i^2. \tag{2}$$

In the absence of a cartel each firm chooses it's price as a Nash best reply to the prices by the others, hence each maximizes

$$\underset{p_i^N}{Max}\ \pi_i^N = p_i^N q_i(p_1^N, ..., p_h^N) - c_i(q_i(p_1^N, ..., p_h^N))$$

or

$$\underset{p_i^N}{Max}\ \pi_i^N = p_i^N \left(A - p_i^N + \frac{1}{h-1}\sum_{j \neq i} p_j^N \right) - \left(A - p_i^N + \frac{1}{h-1}\sum_{j \neq i} p_j^N \right)^2 \tag{3}$$

It follows that the symmetric Nash equilibrium is a solution to the h first order conditions to this problem, equating $p_i^N = p_j^N \forall i, j$ and solving these gives us the Nash equilibrium[4]

$$p_i^N = 3A,\ q_i^N = A,\ \pi_i^N = 2A^2\ \forall i.$$

We take the Nash equilibrium as characterizing the industry in the absence of a cartel.

2.1 Cartel Behavior.

Suppose now that the h firms form a symmetric cartel in which each charges the common price p^C and (given symmetry) produces the same quantity q_i^C. Rewriting (3) using $p_i^N = p_j^N = p^C$ provides

$$\begin{aligned}\pi^C &= p^C \left(A - p^C + \frac{1}{h-1}\sum_{j \neq i} p^C \right) - \left(A - p^C + \frac{1}{h-1}\sum_{j \neq i} p^C \right)^2 \\ &= p^C A - A^2.\end{aligned}$$

We assume that the cartel equilibrium is maintained via a trigger strategy whereby any defection from the cartel price is punished by infinite reversion to the Nash equilibrium[5]. It is assumed that any defection from the cartel remains undetected for one period, thereafter the other cartel members play the punishment strategy. To compute the cartel equilibrium we note that π^C is strictly increasing in p^C, and look for the highest cartel price that the individual firms will have no incentive to defect on. This will be the price at which each firm is just indifferent between defection and remaining in the cartel. Consider first the optimal price that would be chosen by a firm defecting on the cartel.

[4] The functional forms we adopt ensure that the second order conditions for a maximum are satisfied.

[5] See Friedman [4] and Abreu [1] for the theory on trigger strategy equilibria.

2.1.1 Optimal Defection from the Cartel Price.

Given any cartel price be p^C the optimal defection by firm i involves selecting p_i^D so as to

$$\underset{p_i^D}{Max}\ p_i^D\left(A-p_i^D+p^C\right)-\left(A-p_i^D+p^C\right)^2$$

Deriving the first order condition for optimal defection and solving provides

$$p_i^D=\frac{3(A+p^C)}{4},\ q_i^D=\frac{A+p^C}{4},\ \pi_i^D=\frac{(A+p^C)^2}{8}.$$

Temptation to Defect. The temptation to defect is the immediate, one period, gain from defecting on the cartel, and may be written

$$\pi_i^D-\pi_i^C=\frac{(A+p^C)^2}{8}-\left(p^CA-A^2\right) \tag{4}$$

2.1.2 Punishment of Defectors.

If a firm defects on the cartel we assume that the other members punish it in subsequent periods by playing the trigger strategy of an infinite reversion to the Nash equilibrium[6]. Often termed enforcement the penalty imposed on defectors is the sum of the discounted future losses involved from receiving the Nash equilibrium payoff as opposed to that earned in the cartel[7]

Enforcement.

$$\left(\frac{\delta}{1-\delta}\right)(\pi_i^C-\pi_i^N)=\left(\frac{\delta}{1-\delta}\right)\left(p^CA-3A^2\right) \tag{5}$$

2.1.3 Equilibrium.

Any price, p^C, for which enforcement is at least as large as temptation is a candidate for a cartel equilibrium. Equating temptation to enforcement and solving the resultant quadratic yields the range of enforceable cartel prices

$$3A\leq p^C\leq 3A+8A\left(\frac{\delta}{1-\delta}\right).$$

Since we know that profit is increasing in the cartel price, it follows that a profit maximizing cartel selects $p^C=3A+8A\left(\frac{\delta}{1-\delta}\right)$ using this we obtain the cartel equilibrium

$$p_i^C=3A+8A\left(\frac{\delta}{1-\delta}\right),\ q_i^C=A,\ \pi_i^C=2A^2\left(1+4\left(\frac{\delta}{1-\delta}\right)\right)\ \forall i.$$

[6] We neglect for the moment issues of renegotiation (See Farrell and Maskin [3]).

[7] This approach of expressing incentives in terms of temptation and enforcement stems from Baro and Gordon [2].

The gain from cartel membership is thus

$$\pi_i^C - \pi_i^N = 8A^2 \left(\frac{\delta}{1-\delta} \right).$$

The question we wish to analyze is how the introduction of leniency policy effects this cartel equilibrium. There are two distinct possibilities. It may be that with the introduction of leniency policy the cartel may simply no longer be viable, and we should observe a qualitative change in the industry equilibrium to simple one shot Nash. Alternatively, it is possible that the introduction of leniency policy changes the payoffs associated with off-equilibrium actions, and thus has a quantitative effect on the trigger strategy equilibrium, but has no qualitative effects. Hence it does not eliminate cartel behavior. We examine these issues in the next section.

3 Leniency Policy.

Leniency policy, sometimes referred to as amnesty policy, either completely or partially exempts from penalties, those firms or individuals who have violated antitrust laws, provided that they self-report their violations to the antitrust authority. A primary objective of the policy is to bust cartels by providing their members with economic incentives to "squeal" on each other. In essence the policy is an attempt to create a prisoners dilemma. To understand the incentive effects of leniency policies it is clearly necessary to first understand the penalties a squealing firm would avoid and its competitors incur. In most countries that employ a leniency policy the penalties imposed on violators are a combination of the following

1. Corporate fines.
2. Prison sentences for executives found guilty of committing antitrust violations.
3. The establishment of internal mechanisms that ensure future compliance of the firm with antitrust rules.
4. Deportation for foreign nationals involved in antitrust violations.
5. Personal fines for the individual executives involved in the offence.
6. Divestiture of ownership.
7. Restitution to injured parties.

For the purposes of this paper we shall concentrate on the implications of penalties of types 1, 2, 3, and 4. The reason for this emphasis is that we shall argue that these penalties combined with a leniency policy have the potential to provide positive market incentives for firms to squeal on their cartels. That

is in the market equilibrium there are strict gains to the squealer, not just penalties avoided. Penalties of types 5, 6, and 7 tend to fall in the category of losses avoided, and, as Spagnolo [7] has pointed out, these types of penalties have little or no long term deterrence effect on criminal activity. In recognition of this problem Spagnolo argues for "Courageous Leniency Programs" that positively reward squealers. We agree that positive rewards are desirable, but suggest that they are already (at least partially) built into current leniency policies by the way penalties of types 1, 2, 3, and 4 effect economic incentives.

The following table provides information on the penalties imposed by select jurisdictions on antitrust violators.

[Table 1 about here]

3.1 The Incentive to "Squeal".

In certain circumstances leniency policy provides a direct market incentive for cartel members to squeal on their coconspirators and report anti-competitive behavior to the antitrust law enforcing body. If a firm knows that it is going to be fined a portion of it's revenue, or, if it is faces penalties that subsequently raise its costs of production, then a wedge is driven between marginal cost and marginal revenue which effects its behavior and thus the market equilibrium. In these circumstances a firm that squeals and is subsequently given leniency knows that the effects of the penalties on its rivals will gain it a market advantage and increased profits.

3.1.1 Incentive Effects via Revenues.

In each of the countries which we have been able to identify as operating leniency policy, the maximal corporate fines are defined as a proportion of revenues (not profits)[8]. This suggests that by changing marginal revenue the policy may change the firms' market incentives and thus the resultant equilibria. As we shall soon see this tends to benefit the firm that squeals and harms the others. For these effects to occur firms must know at the time they make their pricing decisions that the non-squealers will lose a proportion of their revenues to penalties. There are several circumstances in which this might occur. If, as appears to often occur, there is an overlap between the investigation of alleged antitrust abuses, and the period over which the fine is to be assessed then firms clearly know that a proportion of their revenue will be forfeit[9]. Further, we argue, that at the time that it is announced that leniency policy will introduced forward looking cartels will predict squealing, and there will then be changes in

[8] In some circumstances the fine is based revenue earned in the country where the antitrust case is being brought, in others the fine may be based on worldwide sales.

[9] A brief inspection of footnote 1 or a visit to the Department of Justice web site *http://www.usdoj/atr/public/* reveals that up to two years may pass from the beginning of an antitrust investigation to its conclusion. For example the first round of charges were made in the Lysine case in August 1996, the final penalties were imposed on three ADM executives by a Chicago Grand Jury in September 1998.

the equilibrium[10]. Squealing will not necessarily be observed, as this represent off-equilibrium behavior that only indirectly effects firm behavior. Alternatively we might make the normative argument that when a firm commits antitrust abuses some of the penalties it faces *should* be based on subsequent revenues.

Notice that should a firm decide to squeal on the cartel it does not defect in the usual Bertrand sense of shading its price, rather it triggers an immediate jump to Nash behavior, but it gains extra profit in the resultant equilibrium. The sequence of events is as follows. Suppose that at some time t a firm decides to squeal on its cartel, this immediately becomes known to the other cartel members who switch to Nash behavior, the policy administrator then investigates the accusation. At $t+1$ the policy maker finishes its investigation, finds the cartel guilty, and imposes a proportionate fine of rate η on the past revenue of non-squealers. The squealer is given leniency and faces no penalties.

We denote the price set by the non-squealing firms as p_j^{NS} while the squealer chooses p_i^S further let $\tau = (1-\eta)$. The optimization problem for the squealer may be written

$$\underset{p_i^S}{Max}\ \pi_i^S = p_i^S\left(A - p_i^S + \left(\frac{1}{h-1}\right)\sum_{j\neq i} p_j^{NS}\right) - \left(A - p_i^S + \left(\frac{1}{h-1}\right)\sum_{j\neq i} p_j^{NS}\right)^2$$

which has the first order condition

$$3\left(A - p_i^S + \left(\frac{1}{h-1}\right)\sum_{j\neq i} p_j^{NS}\right) - p_i^S = 0. \tag{6}$$

For the other cartel firms the optimization problems maybe written

$$\underset{p_k^{NS}}{Max}\ \pi_k^{NS} = \tau p_i^S\left(A - p_k^{NS} + \left(\frac{1}{h-1}\right)\left(p_i^S + \sum_{j\neq i} p_j^{NS}\right)\right) - \left(A - p_k^{NS} + \left(\frac{1}{h-1}\right)\left(p_i^S + \sum_{j\neq i} p_j^{NS}\right)\right)^2.$$

The FOCs for all the non-squealing firms is given by

$$(2+\tau)\left(A - p_k^{NS} + \left(\frac{1}{h-1}\right)\left(p_i^{DS} + \sum_{j\neq i} p_j^{NS}\right)\right) - \tau p_k^{NS} = 0 \tag{7}$$

using $p_k^{NS} = p_j^{NS} = p^{NS} \forall j,k$ (4) and (5) become

$$p_i^S = \frac{3(A+p^{NS})}{4},\ p^{NS} = \frac{(2+\tau)}{(h\tau+2)}\left[A(h-1) + p_i^S\right]$$

[10] More on why these expectations might arise in the next section.

Solving for the equilibrium prices gives

$$p^{NS} = \frac{(2+\tau)}{(4h\tau - 3\tau + 2)}\left[A(h-1)\right],\ p_i^S = 3A\left(\frac{2h\tau - \tau + 2h}{4h\tau - 3\tau + 2}\right)$$

We may now immediately solve for the squealers output and profit as

$$q_i^S = A\left(\frac{2h\tau - \tau + 2h}{4h\tau - 3\tau + 2}\right),\ \pi_i^S = 2A^2\left(\frac{2h\tau - \tau + 2h}{4h\tau - 3\tau + 2}\right)^2$$

Notice that the profit obtained from squealing does not depend on the cartel price. Squealing causes a shift from the trigger strategy equilibrium to a Nash equilibrium. The temptation to squeal operating through revenues may be written as

$$\pi_i^{SR} - \pi_i^C = 2A^2\left(\frac{2h\tau - \tau + 2h}{4h\tau - 3\tau + 2}\right)^2 - p^C A + A^2 \tag{8}$$

Notice that the temptation to squeal is increasing in the size of the market (increasing in A), decreasing in industry concentration (increasing in h), and increasing in the magnitude of the fine (η). The market size effect is a scale effect, there is more to be gained by squealing when the market is larger. When industry concentration is lower the non-squealing firms pricing behavior is less effected by the price set by the squealing firm. In this sense Bertrand price competition between the squealing and non-squealing firms is less intense. Thus, in equilibrium, the squealing firm may set a higher price and enjoy greater profits the less concentrated is the industry. That the incentive to squeal is greater the greater is the fine, follows immediately from the fact that a greater fine implies a greater wedge between marginal revenue and marginal cost for the squealing firms rivals.

3.1.2 Incentives Effects via Costs.

The effects that occur via the firms' costs may be thought of as the effects arising from disruptions to the firms operation. When a firm faces an antitrust investigation it will clearly redirect managerial resources into minimizing both the damage to its operations and the subsequent expected penalties [11]. The damage to it's operations might arise from the jailing of key executives, as well as the costs of rebuilding lost reputation[12][13]. Further, once convicted of

[11] From 1993-2000 the US Department of Justice has investigated 727 cases of restraint of trade under the Sherman Act.

Source: Department of Justice, Antitrust Division, Workload Statistics, at *http://www.osdoj.gov/atr/*

[12] From the revision of the DOJ's antitrust policies in 1993 through the year 2000, 98 corporate executives have been sentenced to a total of 26,892 days of incarceration. A further 136 executives have been sentenced to other forms of confinement (mainly house arrest) for a total 18,325 days. A total of 234 executives confined for a total of 124 years.

Source: Department of Justice, Antitrust Division, Workload Statistics, at *http://www.osdoj.gov/atr/*

[13] In the famous cases discussed earlier 7 executives involved in the Vitamins cartel recieved jail sentences, in the Graphite electrodes case 2 executives were incarcerated, while in the

antitrust abuses a firm is often made to introduce costly internal mechanisms that ensure future compliance with the antitrust laws.

We suggest that each of these will tend to raise firms costs. Such that we now write the individual firms profit functions as

$$p_i\left(A-p_i+\frac{1}{h-1}\sum_{j\neq i}p_j\right)-\beta\left(A-p_i+\frac{1}{h-1}\sum_{j\neq i}p_j\right)^2$$

where $\beta>1$ is a simple way to capture the effects on cost of the disruptive effects 1-3. Solving for the equilibrium in an identical manner to the revenue case we obtain the equilibrium prices

$$p^{NS}=\frac{(2\beta+1)}{(4h-3+2\beta)}\left[A(h-1)\right],\ p_i^S=3A\left(\frac{2h-1+2\beta h}{4h-3+2\beta}\right)$$

We may now immediately solve for the squealers quantity and profit as

$$q_i^S=A\left(\frac{2h-1+2\beta h}{4h-3+2\beta}\right),\ \pi_i^S=2A^2\left(\frac{2h-1+2\beta h}{4h-3+2\beta}\right)^2$$

Notice that the profit obtained from squealing does not depend on the cartel price. Squealing causes a shift from the trigger strategy equilibrium to a Nash equilibrium. The temptation to squeal arising from the cost incentives may now be written as

$$\pi_i^{SC}-\pi_i^C=2A^2\left(\frac{2h-1+2\beta h}{4h-3+2\beta}\right)^2-p^CA+A^2 \tag{9}$$

We see immediately that exactly as with revenue incentives the temptation to squeal is increasing in the size of the market (increasing in A), decreasing in industry concentration (increasing in h), and increasing in the magnitude of the fine (η). The explanations are essentially the same as in the cost case.

3.1.3 Overall Temptation to Squeal.

Combining the revenue and cost incentives to squeal (8) and (9) and discounting appropriately we obtain

$$\left(\pi_i^{SR}-\pi_i^C\right)+\delta\left(\pi_i^{SC}-\pi_i^C\right)=2A^2\left(\frac{2h\tau-\tau+2h}{4h\tau-3\tau+2}\right)^2-p^CA+A^2$$
$$+\delta\left[2A^2\left(\frac{2h-1+2\beta h}{4h-3+2\beta}\right)^2-p^CA+A^2\right]$$

Lysine case 4 executives recieved jail sentences.

Source: Selected Criminal Cases, Antitrust Division, US Department of Justice, at *http://www.usdoj.gov/atr/public/4523.htm*

3.2 Equilibrium with Leniency Policy.

We now have all the components needed to analyze the equilibria that may arise in the presence of leniency policy. Consider a firm which is a member of a cartel at the time leniency policy is introduced. It has three options; (1) To remain in the cartel, (2) to defect from the cartel by optimally undercutting the cartel price, (3) to self-report the cartels prior activities to the antitrust authority. If a firm were to choose either of options 2 or 3 the outcome will be a profit gain for two periods followed by a loss associated with a reversion to Nash in all subsequent periods, hence we would have enforcement as before except that the loss needs to be discounted two periods into the future, hence

Enforcement

$$\left(\frac{\delta^2}{1-\delta}\right)\left(\pi_i^C - \pi_i^N\right) = \left(\frac{\delta^2}{1-\delta}\right)\left(p^C A - 3A^2\right)$$

If leniency is to be an effective antitrust policy it must provide cartel members with as much incentive to leave as the standard option of defecting. We consider this next.

3.2.1 Defection vs Squealing.

If the firm decides to leave the cartel it may either defect or squeal but not both. Implicit in this assumption is the idea that once a firm squeals the others play Nash[14]. At this point it is important to get the timing of events clear. At time t the firm chooses between the options outlined above. If it chooses to remain in the cartel it earns cartel profits thereafter. If it chooses to defect it earns the defection profit for one period $t \rightarrow t+1$, and then faces the other firms playing Nash thereafter. If it chooses to squeal it triggers an investigation by the antitrust authority that is assume to last from $t \rightarrow t+1$, for this period it reaps the revenue advantage generated because other firms play Nash and are aware that they will be fined a proportion of the income gained in $t \rightarrow t+1$. At $t+1$ the other firms are found guilty of antirust violations and face the punishments that effect their costs, the squealing firm then gains the cost advantage associated with this from $t+1 \rightarrow t+2$. From $t+2$ onward all firms play Nash.

If the firm defects its payoff is the gain termed temptation defined by (4), while the subsequent penalties it faces termed enforcement are as defined by (5). If, on the other hand, the firm chooses to squeal its payoff gain defines the

[14] It is noticable that when a firm decides to cooperate with the antitrust authority it usually holds a press conference to announce the fact. This seems consistent with the squealer ensuring that it achieves a market advantage by making the other cartel members aware that they are about to face penalties

Temptation to Squeal.

$$\begin{aligned}
&\left(\pi_i^{SR} - \pi_i^C\right) + \delta\left(\pi_i^{SC} - \pi_i^C\right) \\
&= 2A^2\left(\frac{2h\tau - \tau + 2h}{4h\tau - 3\tau + 2}\right)^2 - p^C A + A^2 \\
&+\delta\left[2A^2\left(\frac{2h - 1 + 2\beta h}{4h - 3 + 2\beta}\right)^2 - p^C A + A^2\right]
\end{aligned}$$

and the subsequent penalties if the firm squeals are given by the standard enforcement expression discounted two periods into the future

Enforcement after Squealing.

$$\left(\frac{\delta^2}{1-\delta}\right)\left(\pi_i^C - \pi_i^N\right) = \left(\frac{\delta^2}{1-\delta}\right)\left(p^C A - 3A^2\right)$$

If follows than that squealing will be preferred to defection if

$$\begin{aligned}
&2A^2\left(\frac{2h\tau - \tau + 2h}{4h\tau - 3\tau + 2}\right)^2 - p^C A + A^2 \\
&+\delta\left[2A^2\left(\frac{2h - 1 + 2\beta h}{4h - 3 + 2\beta}\right)^2 - p^C A + A^2\right] \geq \\
&\frac{(A + p^C)^2}{8} - \left(p^C A - A^2\right) + \delta(3A^2 - p^C A)
\end{aligned}$$

where the last term in this expression is the loss due to enforcement in the second period. Simplifying this expression we obtain the condition

$$\begin{aligned}
&2A^2\left(\frac{2h\tau - \tau + 2h}{4h\tau - 3\tau + 2}\right)^2 + \delta\left[2A^2\left(\frac{2h - 1 + 2\beta h}{4h - 3 + 2\beta}\right)^2\right] \geq \\
&\frac{(A + p^C)^2}{8} + 2\delta(A^2)
\end{aligned} \tag{10}$$

we now immediately have

Proposition 1 *Squealing will be "relatively more likely" than defecting, (1) The greater is δ, (2) The smaller is τ (the greater is η), (3) The greater is β, (4) the greater is h..*

Proof. Follows immediately from differentiating condition (10) above with respect to the appropriate variable. ■

When squealing takes place the squealing firm enjoys a market advantage for two periods, when the firm defects it enjoys a market advantage for the first period, but incurs punishment in the second. Thereafter the payoffs are the same with both squealing and defecting. Hence the greater is δ the relatively

more attractive will be the option of squealing. The greater is η the larger will be the fines paid by the non-squealers in the squealing case. This implies that the squealer will earn greater profits from squealing, and hence makes this option relatively more attractive. A similar explanation applies to the effects of β. When industry concentration is lower the non-squealing firms pricing behavior is less effected by the price set by the squealing firm. The squealing firm thus makes greater profits (see the discussion above). Industry concentration does not effect defection profits in this model, hence the less concentrated is the industry the relatively more attractive is squealing.

3.2.2 Equilibrium.

The equilibrium in the model may now be either the original cartel equilibrium, if the incentives introduced by leniency policy are insufficient to induce squealing, or, Nash, if squealing will eliminate the cartel. These possibilities are illustrated in figures 1 and 2. On each figure we have the temptation to defect on the cartel, the temptation to squeal, and the enforcement incurred by a defector or squealer[15].

[15] The temptation to squeal and enforcement after squealing loci have each be multiplied by δ, so that they be expressed together with the temptation to defect and appropriate enforcement loci.

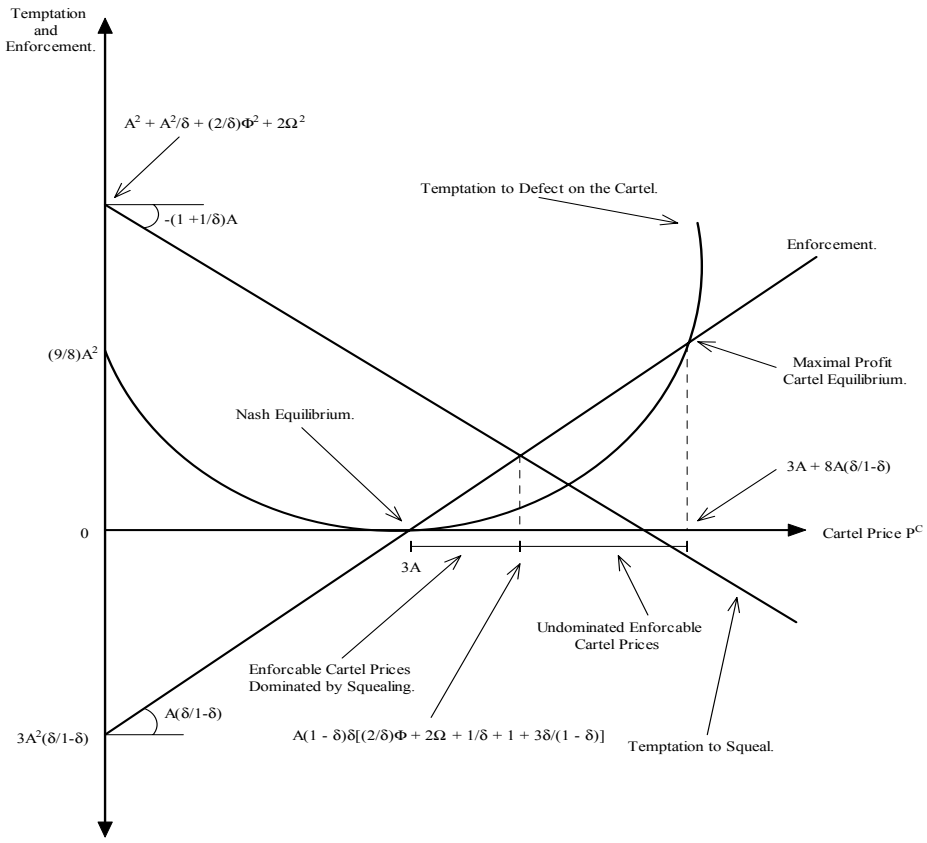

Figure 1: When Leniency Policy does not Eliminate the Cartel.

In figure 1 for all cartel prices in the range

$$0 \leq p^C \leq A(1-\delta)\delta[(\frac{2}{\delta})\Phi + 2\Omega + \frac{1}{\delta} + 1 + 3\frac{\delta}{1-\delta}]$$

where $\Phi \equiv \left(\frac{2h\tau-\tau+2h}{4h\tau-3\tau+2}\right)^2$ and $\Omega \equiv \left(\frac{2h-1+2\beta h}{4h-3+2\beta}\right)^2$, the gain form squealing is greater than both enforcement, and the gain from defecting, but over the range

$$A(1-\delta)\delta\left[\left(\frac{2}{\delta}\right)\Phi + 2\Omega + \frac{1}{\delta} + 1 + 3\left(\frac{\delta}{1-\delta}\right)\right] > p^C \geq 3A + 8A\left(\frac{\delta}{1-\delta}\right)$$

it is more profitable for firms to remain in the cartel. Since maximal cartel profit occurs at $p^C = 3A + 8A\left(\frac{\delta}{1-\delta}\right)$ the model predicts that for the range of parameter values for which this diagram is valid there would be no effect of leniency policy on cartel behavior. Suppose, however, that the temptation to squeal is a little greater we then get

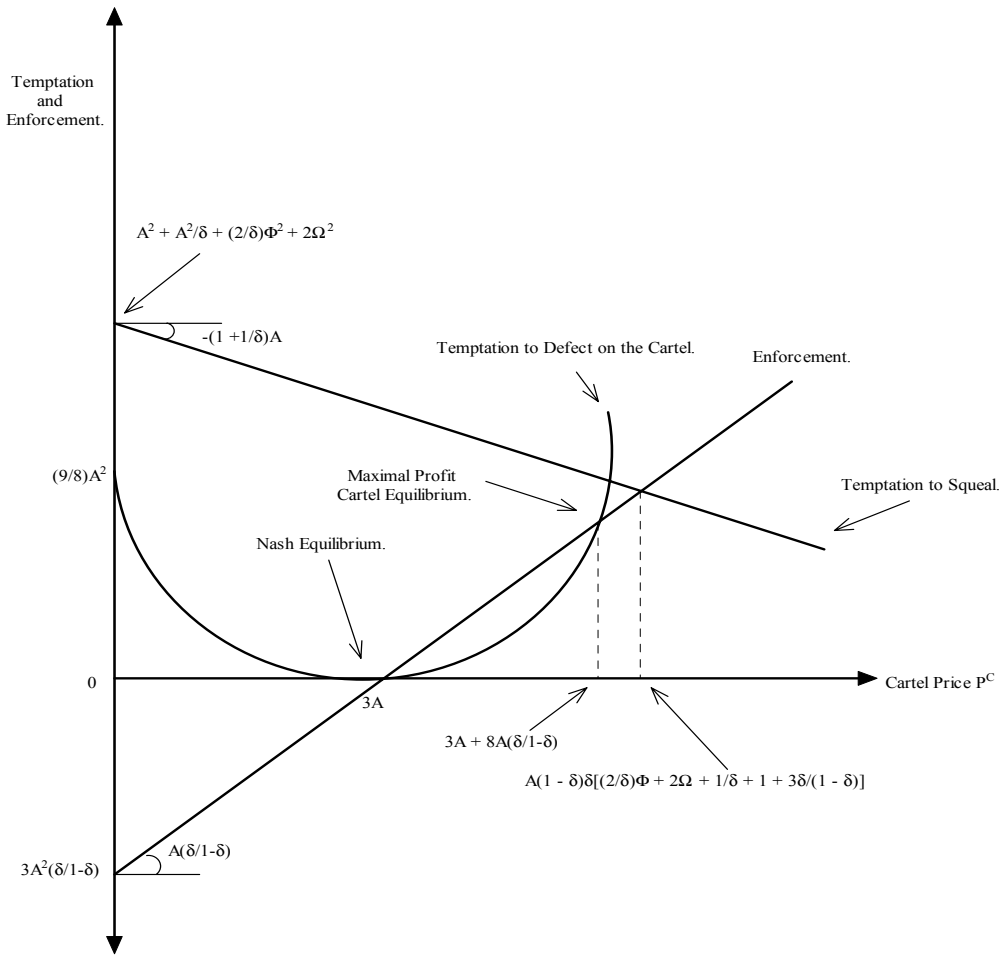

Figure 2: When Leniency Policy Eliminates the Cartel.

In figure 2 we represent the case where $A(1-\delta)\delta\left[(\frac{2}{\delta})\Phi + 2\Omega + \frac{1}{\delta} + 1 + 3\frac{\delta}{1-\delta}\right] < 3A + 8A\left(\frac{\delta}{1-\delta}\right)$ here there is no cartel price at which a firm would prefer to stay in the cartel rather than squeal. There exist standard trigger strategy equilibria but all of these are dominated by the squealing strategy. Thus all firms would squeal once the leniency policy was introduced and the resultant equilibrium in all subsequent periods would be Nash.[16] We should be careful at this point to emphasize that the model does not predict that squealing will be observed in this case, rather it is the off equilibrium threat of squealing that causes a reversion to Nash, which is the only feasible equilibrium. All that would be observed would be a fall in the cartel price to $p_i^N = 3A$.

[16] It is an easy task to show that there exist sensible parameter values consistent with figure 1 and other similarly sensible parameter values consistent with figure 2.

4 Squealing as a Trigger Strategy.

We now consider the possibility that squealing may be adopted by cartels as part of the punishment or trigger strategy. In these circumstances if a firm defects but does not squeal the other cartel members may punish it by squealing to the antitrust authority and then playing Nash for all subsequent periods[17]. This, as we shall demonstrate, both reduces the defectors defection profits, and increases the enforcement penalty that the cartel members can impose on a defector. Furthermore, the addition of squealing allows the firms engaged in punishment to earn greater profits than obtained in the simple symmetric Nash equilibrium. Thus, under corporate leniency policy, there exist weakly negotiation proof cartel equilibria other than the symmetric Nash. this is true even though renegotiation is costless.

4.1 Temptation.

When a firm defects from the cartel, and the cartel is using squealing as part of the punishment strategy, this is known to the defecting firm at the time it defects. The defecting firm therefore knows that it will lose part of the "defection profits" to the fine it will ultimately pay and will then also face the cost disadvantages outlined above. We define π_i^{DF} as the profit the defecting firm will earn in the defection period and p_i^{DF} as the price it will set. We now need to recalculate the cartel equilibrium under optimal defection when squealing is part of the punishment.

4.1.1 Optimal Defection on the Cartel Price.

Given any cartel price p^C the optimal defection by firm i involves selecting p_i^{DF}so as to

$$\underset{p_i^{DF}}{Max}\ \tau p_i^{DF}\left(A - p_i^{DF} + p^C\right) - \left(A - p_i^{DF} + p^C\right)^2$$

which recognizes that it will subsequently face fines at the rate η (recall $\tau = 1 - \eta$). From the first order condition for the defecting firm we may solve to obtain

$$p_i^{DF} = \frac{(2+\tau)(A+p^C)}{2(1+\tau)},\ q_i^{DF} = \frac{\tau(A+p^C)}{2(1+\tau)},\ \pi_i^{DF} = \frac{\tau^2(A+p^C)^2}{4(1+\tau)}.$$

So the immediate, one period, gain from defecting on the cartel, may be written

$$\pi_i^{DF} - \pi_i^C = \frac{\tau^2(A+p^C)^2}{4(1+\tau)} - \left(p^C A - A^2\right)$$

[17] Spagnolo [8]has noted that leniency programs may solve the Bertrand Paradox and enforce collusion in auctions. The idea being that leniency allows squealing to be a credible enforcement strategy in a one-shot-game.

From our previous analysis we know that in the absence of leniency policy the temptation to defect on the cartel is given by

$$\pi_i^D - \pi_i^C = \frac{(A+p^C)^2}{8} - \left(p^C A - A^2\right)$$

We immediately have

Proposition 2 *For all positive cartel prices $p^C > 0$ and for all positive fine rates $\eta > 0$ the temptation to defect is lower with leniency policy.*

Proof. Follows immediately from noting that since $\eta > 0 \Rightarrow \tau < 1$, then $\frac{\tau^2(A+p^C)^2}{4(1+\tau)} - \left(p^C A - A^2\right) < \frac{(A+p^C)^2}{8} - \left(p^C A - A^2\right) \Rightarrow \pi_i^{DF} - \pi_i^C < \pi_i^D - \pi_i^C$. ■

A defecting firm knows that it will lose part of its extra profits in the form of fines imposed by the antitrust authority, and hence finds defection less attractive.

4.2 Enforcement.

We assume that when a firm is detected defecting by the cartel they all then squeal and play Nash. Given that the squealing in this case is likely to lead to a swift investigation and prosecution we assume that the penalties are imposed immediately (investigation and punishment period do not overlap as the investigation period is so short)[18]. To define enforcement we need to compute the Nash equilibrium for the next period immediately after the defection has been detected, in this period the other cartel firms play Nash and squeal on the defector.

Here for the first period after the defection is detected the defector chooses the price p_i^{DV} which maximizes

$$\underset{p_i^D}{Max}\ \pi_i^{DV} = p_i^{DV}\left(A - p_i^{DV} + \left(\frac{1}{h-1}\right)\sum_{j\neq i} p_j^{CS}\right) - \beta\left(A - p_i^{DV} + \left(\frac{1}{h-1}\right)\sum_{j\neq i} p_j^{CS}\right)^2$$

given that the cartel firms have chosen $p_j^{CS} = p^{CS} \forall j$ the FOC's involve

$$(1+2\beta)\left(A - p_i^{DV} + \left(\frac{1}{h-1}\right)\sum_{j\neq i} p_j^{CS}\right) - p_i^{DV} = 0. \tag{11}$$

[18] Al but one of the firms are cooperating with the antitrust authority.

Each cartel member now plays Nash given that the defector faces the fine. So the cartel members optimization problems involve

$$\underset{p_j^{CS}}{Max}\ \pi_j^{CS} = p_j^{CS}\left(A - p_j^{CS} + \frac{p_i^{DV}}{h-1} + \left(\frac{1}{h-1}\right)\sum_{k\neq j\neq i} p_k^{CS}\right) - \left(A - p_j^{CS} + \frac{p_i^{DV}}{h-1} + \left(\frac{1}{h-1}\right)\sum_{k\neq j\neq i} p_k^{CS}\right)^2$$

which provides FOC's

$$3\left(A - p_j^{CS} + \frac{p_i^{DV}}{h-1} + \left(\frac{1}{h-1}\right)\sum_{k\neq j\neq i} p_k^{CS}\right) - p_j^{CS} = 0. \tag{12}$$

Using (11) and (12) we may solve for p_i^{DV} and p_j^{CS} and thus obtain π_i^{DV}.

Enforcement in the first period of punishment is now written

$$\delta\left(\pi_i^C - \pi_i^{DV}\right)$$

in subsequent periods the equilibrium reverts to the symmetric Nash and we get

$$\left(\frac{\delta^2}{1-\delta}\right)\left(\pi_i^C - \pi_i^N\right)$$

hence, in total,enforcement becomes

$$\delta\left(\pi_i^C - \pi_i^{DV}\right) + \left(\frac{\delta^2}{1-\delta}\right)\left(\pi_i^C - \pi_i^N\right)$$

To demonstrate that enforcement increases with the introduction of leniency policy we need to show that it is increasing in β, referring back to (6) we see that this follows if $\pi_i^{DV} < \pi_i^N$.

Proposition 3 *For every positive cartel price enforcement is greater with leniency policy than in its absence.*

Proof. Note first that expressions (11) and (12) with $p_k^{CS} = p_j^{CS} \equiv p^{CS}$ define reaction functions for the cartel firms (jointly) and the defecting firm which may be written

$$\begin{aligned} p_i^{DV} &= \left(\frac{1+2\beta}{2+2\beta}\right)(A + p^{CS}) \\ p^{CS} &= \left(\frac{3}{h+2}\right)\left(A(h-1) + p_i^{DV}\right) \end{aligned}$$

Note the reaction functions have the following properties

(1) Both reaction functions have positive slope in price space.

(2) The defecting firms reaction function has slope less than unity, the cartel's (joint) reaction function has positive slope greater than unity implying a unique equilibrium.

(3) The slope and intercept of the defecting firms reaction function are both increasing in β.

These properties imply that an increase in β raises both p_i^{DV} and p^{CS} as a shift along the cartel's reaction function. To show that $\pi_i^{DV} < \pi_i^N$ all that now remains is to show that π_i^{DV} is decreasing with an increase in p_i^{DV} along the cartels reaction function. Substituting for p^{CS} gives

$$\pi_i^{DV} = p_i^{DV}\left[\left(\frac{h+5}{h+2}\right)A + \left(\frac{1-h-h^2}{(h-1)(h+2)}\right)p_i^{DV}\right] \\ -\beta\left[\left(\frac{h+5}{h+2}\right)A + \left(\frac{1-h-h^2}{(h-1)(h+2)}\right)p_i^{DV}\right]^2$$

simple differentiation yields $\frac{\partial \pi_i^{DV}}{\partial p_i^{DV}} < 0$ which is clearly a sufficient condition for $\frac{\partial \pi_i^{DV}}{\partial \beta} < 0$. ■

4.3 Temptation and Enforcement with Squealing as a Trigger Strategy.

If squealing does not eliminate the cartel but rather acts as part of the trigger strategy the effects on the equilibrium are as illustrated in figure 3

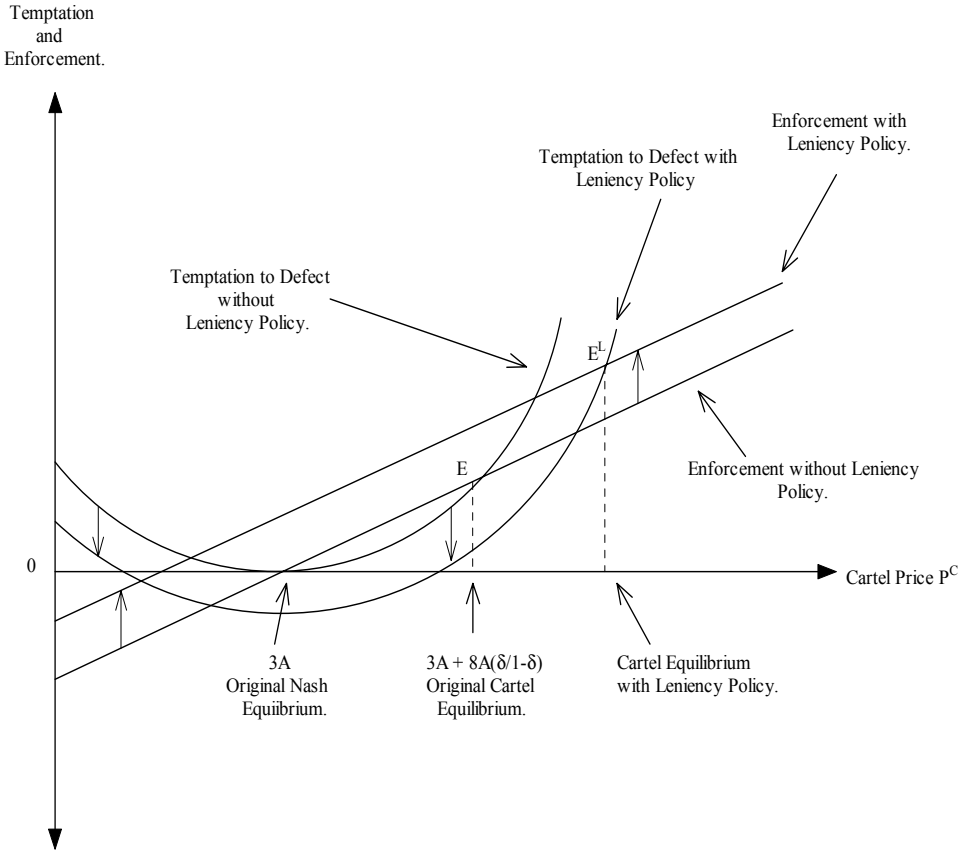

Figure 3: Effects of Squealing as a Trigger Strategy.

As the diagram illustrates the introduction of leniency policy which subsequently becomes part of the cartel's trigger strategy shifts both the temptation and enforcement curves. The cartel equilibrium moves from point E to point E^L, with a subsequent increase in the cartel's best enforceable price and its profits. Hence "what does not hurt us makes us stronger."

4.4 Renegotiation Proofness.

In the punishment phase of the game squealing by the non-defecting firms serves to provide them with a market advantage that raises their profits above those enjoyed in the simple symmetric Nash equilibrium. This can serve the same function as the small renegotiation costs discussed by McCutcheon [5] and hence there exist weakly renegotiation proof cartel equilibria other than the symmetric Nash. In these weakly renegotiation proof cartel equilibria all firms earn greater profits.

To be renegotiation proof a cartel equilibrium must be such that once in the punishment phase the punishing firms are indifferent between enacting the

punishment and returning to the cartel equilibrium. In our simple model this implies that the punishment phase can last only as long as leniency policy provides the punishers with a market advantage, assumed above to be one period, thus the condition for the cartel equilibrium to be weakly renegotiation proof is simply

$$\pi_j^{CS} \geq \pi_j^C \geq \pi^N \text{ one inequality strict.}$$

Proposition 4 *There exist weakly renegotiation proof cartel equilibria such that* $\pi_j^C > \pi^N$.

Proof. As noted above all that is required to establish the proposition is that $\pi^{CS} > \pi^N$. First notice that if $\beta = 1$ then we have the standard symmetric Nash case and we know $\pi^{CS} = \pi^N$. Suppose now that β increases, proposition (3) establishes that both p_i^{DV} and p^{CS} increase as the equilibrium shifts along the cartel's (joint) reaction function. Hence all we need to show to establish the proposition is that $\frac{d\pi_j^{CS}}{dp_i^{DV}} > 0$ along the cartel's joint reaction function. Substituting the cartels reaction function into one of its members profit functions provides

$$\begin{aligned}\pi_j^{CS} = &\left(\frac{3}{h+2}\right)\left(A(h-1)+p_i^{DV}\right)\\ &\times\left[A-\left(\frac{3}{h+2}\right)\left(A(h-1)+p_i^{DV}\right)\left(\frac{1}{h-1}\right)+\frac{p_i^{DV}}{h-1}\right]\\ &-\left(A-\left(\frac{3}{h+2}\right)\left(A(h-1)+p_i^{DV}\right)\left(\frac{1}{h-1}\right)+\frac{p_i^{DV}}{h-1}\right)^2\end{aligned}$$

differentiating wrt p_i^{DV} yields

$$\begin{aligned}\frac{d\pi_j^{CS}}{dp_i^{DV}} = &\left(\frac{3}{h+2}\right)\left[A-\left(\frac{3}{h+2}\right)\left(A(h-1)+p_i^{DV}\right)\left(\frac{1}{h-1}\right)+\frac{p_i^{DV}}{h-1}\right]\\ &-\left(\frac{3}{h+2}\right)^2\left(A(h-1)+p_i^{DV}\right)\left(\frac{1}{h-1}\right)\\ &+\left(\frac{3}{h+2}\right)\left(A(h-1)+p_i^{DV}\right)\left(\frac{1}{h-1}\right)\\ &+2\left[A-\left(\frac{3}{h+2}\right)\left(A(h-1)+p_i^{DV}\right)\left(\frac{1}{h-1}\right)+\frac{p_i^{DV}}{h-1}\right]\\ &\times\left[\left(\frac{3}{h+2}\right)\left(\frac{1}{h-1}\right)-\left(\frac{1}{h-1}\right)\right]\end{aligned}$$

it is easy to show

$$\left(\frac{3}{h+2}\right)\left(A(h-1)+p_i^{DV}\right)\left(\frac{1}{h-1}\right) > \left(\frac{3}{h+2}\right)^2\left(A(h-1)+p_i^{DV}\right)\left(\frac{1}{h-1}\right)$$

and

$$\left(\frac{3}{h+2}\right)\left[A-\left(\frac{3}{h+2}\right)\left(A(h-1)+p_i^{DV}\right)\left(\frac{1}{h-1}\right)+\frac{p_i^{DV}}{h-1}\right]$$
$$>2\left[A-\left(\frac{3}{h+2}\right)\left(A(h-1)+p_i^{DV}\right)\left(\frac{1}{h-1}\right)+\frac{p_i^{DV}}{h-1}\right]$$
$$\times\left[\left(\frac{3}{h+2}\right)\left(\frac{1}{h-1}\right)-\left(\frac{1}{h-1}\right)\right]$$

hence $\frac{d\pi_j^{CS}}{dp_i^{DV}}>0$ as required. ■

5 Cartel Identification.

The analysis in the preceding section provides a potentially useful too for identifying cartels. The model predicts that the introduction of leniency policy will lead to observable changes in pricing behavior, such that cartels may reveal themselves[19]. We would anticipate that prices in competitive industries will be unaffected by the introduction of leniency policy. However, prices in cartels that are eliminated by leniency policy will fall even if no squealing takes place. Further, prices in those cartels which are not eliminated by leniency policy will rise with the policies introduction. These simple predictions suggests that this may be fertile ground for future empirical work.

6 Conclusion.

In this paper we have provided an analysis of corporate leniency policy. In the context of a simple model of Bertrand competition with differentiated products we are able to illustrate circumstances where the policy is an effective tool for the prevention of anti-competitive behavior, and where it only tends to exacerbate antitrust abuses. We find that the introduction of leniency policy allows some firms to gain a market advantage from self-reporting their cartel membership. This occurs because an adverse wedge is driven between marginal cost and marginal revenue for those firms that do not enjoy leniency. However, this may encourage a firm to squeal and report cartel membership, or it may operate as an enforcement mechanism to enhance the cartel. Further the policy makes a range of equilibrium cartel prices renegotiation proof by providing enforcers with a credible punishment strategy.

There are however several features both of recent economic experience, and of leniency policy itself that we are unable to explain within the strict limits of our model . First it should be noted that in our analysis the effects of the policies work through the off-equilibrium payoffs, thus while we predict changes in cartel prices, and even the dissolution of some cartels, we do not predict that any antitrust cases should be observed. Clearly this is at odds

[19] Provided that they have not anticipated this paper!

with the evidence, but we do not believe this is a fundamental problem. We have assumed a situation where antitrust cases stem only from self reporting by cartel members, and, further, we have assumed all cases reported then result in successful prosecution. Were we to allow for random audits, or some source of stochasticness in individual pricing, then it would not be too difficult a step to extend our model to explain the occurrence of prosecutions.

Corporate leniency as operated by the U.S. Department of Justice provides full amnesty for the first squealer and partial leniency for firms that subsequently cooperate. In our model this policy is inexplicable. Leniency for the second squealer only dilutes the market advantage enjoyed by the first and thus makes squealing less attractive. We are generally skeptical about the efficacy of this component of the policy, but suspect it can be rationalized in a model where the results of an antitrust prosecution are uncertain. It might be worth diluting the initial incentive to squeal, if in return the probability of a successful prosecution rises sufficiently. These are however issues we wish to explore in future work, our objective in this paper has been to suggest some direct economic incentives to explain the effects of leniency policy on cartel behavior.

References

[1] Abreu, Dilip. "Extremal Equilibria for Oligopolistic Supergames," *Journal of Economic Theory*, June 1986, 39(1), pp. 191-225.

[2] Barro, Robert, and Gordon, David. "Rules Discretion and Reputation in a Model of Monetary Policy".

Journal of Monetary Economics,. 12, 1983, pp 101-121.

[3] Farrell, Joseph, and Maskin, Eric. "Renegotiation in Repeated Games," *Games and Economic Behavior*, 1(4), 1989, pp 327-360.

[4] Friedman, James. "A Noncooperative Equilibrium for Supergames," *Review of Economic Studies*, Jan. 1971, 38(113), pp 1-12.

[5] McCutcheon, Barbara. "Do Meetings in Smoke-Filled Rooms Facilitate Collusion?" *Journal of Political Economy*, April 1997, 105(2), pp 330-350.

[6] Motta, Massimo, and Polo, Michele. "Leniency Programs and Cartel Prosecution," Working Paper ECO No. 99/23, July 1999, European University Institute.

[7] Spagnolo, Giancarlo. "Optimal Leniency Programs" Fondazione Eni Enrico Mattei, Nota di Lavoro 42.2000, May 2000.

[8] Spagnolo, Giancarlo. "Self-Defeating Antitrust Laws: How Leniency Programs Solve Bertrand's Paradox and Enforce Collusion in Auctions" Fondazione Eni Enrico Mattei, Nota di Lavoro 52.2000, June 2000.