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THE DEPARTMENT OF JUSTICE LENIENCY PROGRAM AND THE DISSOLUTION OF CARTELS IN A GAME OF MIXED STRATEGIES

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ABSTRACT

Cartels cause harm to economic markets as they charge higher than normal prices and supply a lower quantity than a market that is operating under competition. Since cartels are mostly secretive agreements, society does not know how many cartels are currently, or have been, in operation. The U.S. Department of Justice devotes resources to successfully discover and prosecute cartels to return the market into a competitive balance. In 1993, the Department of Justice implemented its Leniency Program, which would give firms reduced fines for self-reporting their involvement. Many papers have sought to analyze how this policy affects the incentive structure of colluding firms, and have searched for the optimal policy. This paper seeks to advance on the framework that has been put in place by previous authors, while synthesizing and clarifying some of the existing literature. This paper will also examine how the Leniency Program will function under the conditions of an increasing probability of investigation and conviction in a game of mixed strategies.

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Chapter 1

Introduction

The Sherman Act of 1890 made anti-competitive business activity, like collusion, illegal in the United States. Up until 1993, the Department of Justice (DOJ) relied entirely on its own enforcement efforts to detect and prosecute anti-competitive activity. Cartels can cause considerable harm to the United States economy; hence the DOJ continues to aggressively pursue firms engaged in criminal price fixing, or any other form of collusion.[1] The DOJ receives information from a variety of avenues, including: complaints from trade groups or competitors, and collaboration with foreign anti-trust agencies and state agencies. In 1993, the DOJ added another tool of enforcement with the implementation of the Leniency Program.[2] The Leniency Program offers reduced fines to firms that come forward and self-report their involvement in a cartel. Through this policy, the DOJ has altered the underlying incentive structure of the firms engaged in collusion. Colluding firms previously would worry if their partners would cheat on the agreement, but now they must also worry if the firms will take advantage of the Leniency Program.

Within economic study, papers and research attempt to identify the underlying incentive structures and how changes in the environment affect the status quo. This paper will seek to examine and synthesize the existing literature surrounding the Leniency Program, and examine how the policy functions in a game of mixed strategies when the probability of investigation and conviction are increasing over time. The first step of this paper will give a brief overview of

[1] Baer and Hosko (2013)
[2] Wilkinson (2014)

cartels and the role of incentives within collusive agreements before moving on to dissecting the Leniency Program and examining its stipulations.

1.1: Basic Principles of Cartels

People and firms respond to incentives by changing their behavior. In a competitive market, firms compete to gain market share and maximize their profits. Under the competitive structure, assuming homogenous products, companies have the incentive to drop their price relative to their competitors in order to sell more units of a good. However, all firms face the same incentive which results in a price war. Firms will keep dropping the price until it reaches a point where their price is equal to the marginal cost of production. At this point, the firms do not have any other incentive to drop price, and hence an equilibrium is reached.[3]

With the incentive to compete comes an incentive to collude. Rational firms can see the benefits of colluding with other firms in the industry to artificially raise the price of a product, relative to what the market demands. As a result from these actions, consumer welfare is hurt as they are now paying a higher price, while having a reduced supply on the market. Firms that were once competing have become a group of monopolists, which is accepted as harmful to economic well-being.

Collusion can either be explicit or tacit. Explicit collusion requires firms to actively engage in communication to maintain prices and supply levels, while preventing other firms from undercutting their efforts. Explicit collusion, as a result of the meetings and communication, generally helps to create a paper trail of evidence that the DOJ could use in investigations. Tacit collusion, on the other hand, is when companies agree on a price or quantity, without ever

[3] Of course, firms could engage in predatory pricing and price below their marginal cost in order to force competition out of the market or deter entry.

actually expressing those details through communication. In the interests of this paper, I will be assuming the firms are engaged in explicit collusion, as it requires more active participation and generates more evidence for the DOJ to examine.

With collusive agreements, firms have an incentive to defect as they could cheat on the agreement by lowering their price, and then capture a larger market share. One of the underlying problems of collusion is the issue of trust; the trust that your partners will remain committed to the agreements despite the fact that they are not enforceable in court. The DOJ has added an additional incentive to defect from the agreement, and in doing so, added another layer of distrust. The firms now must worry about a firm reporting the cartel to the DOJ, as well as firms who may be cheating on the agreement.

1.2: Department of Justice Leniency Program

The DOJ Leniency Program, also known as the Amnesty Policy, has become "the most important investigative tool for detecting cartel activity" by offering companies and individuals the ability to "avoid criminal conviction, fines, and prison sentences".[4] The Leniency Program allows firms to avoid or mitigate the costly fines and criminal penalties that are levied against firms guilty of collusion. In order to be eligible for leniency, a corporation must meet these three major requirements of the policy. Under these initial conditions, this is generally referred to as Type A Amnesty.

1. The DOJ must not have any prior knowledge regarding the cartel.

[4] *www.justice.gov*.

2. Upon learning of the cartel, the company must have taken prompt-action to end its involvement.[5]
3. The member agrees to fully participate in the subsequent investigation.

As time has gone on, the DOJ has added variations of leniency to help provide current cartel members more of an incentive to self-report. Type B Amnesty allows a firm to receive leniency even if the DOJ has previous information or is currently examining the cartel in question. Of all amnesty applicants, 80-90% are considered Type B applicants.[6] Additionally, Amnesty Plus was created to allow for separate product leniency. Many colluders are engaged in collusion over multiple products, and papers such as Marshall et al (2013) and Lefouili and Roux (2012) have examined this issue in the setting of the Leniency Program. A firm that is discovered in another cartel, but was not the first to report and therefore not eligible for leniency in that product, may apply for leniency in a separate product. The company then may be able to receive a fine reduction in both products, thus offering them an incentive to turn over additional evidence of collusion.

The benefits from applying for leniency only deal with the firm's liability to the federal government. The firms, however, are now opened up to additional litigation from the private sector. The consumers that were hurt by these firms' actions are entitled to damages; they have over paid for a product and will want to receive compensation. Private litigation has a unique characteristic that can make collusion costly for firms – treble damages. Treble damages allow for the damages to be tripled; for example, $100 million in actual damages could be trebled to $300 million that the firm would have to pay out to the hurt parties. Under American anti-trust law, a leniency applicant may be able to de-treble their damages if it cooperates with the hurt

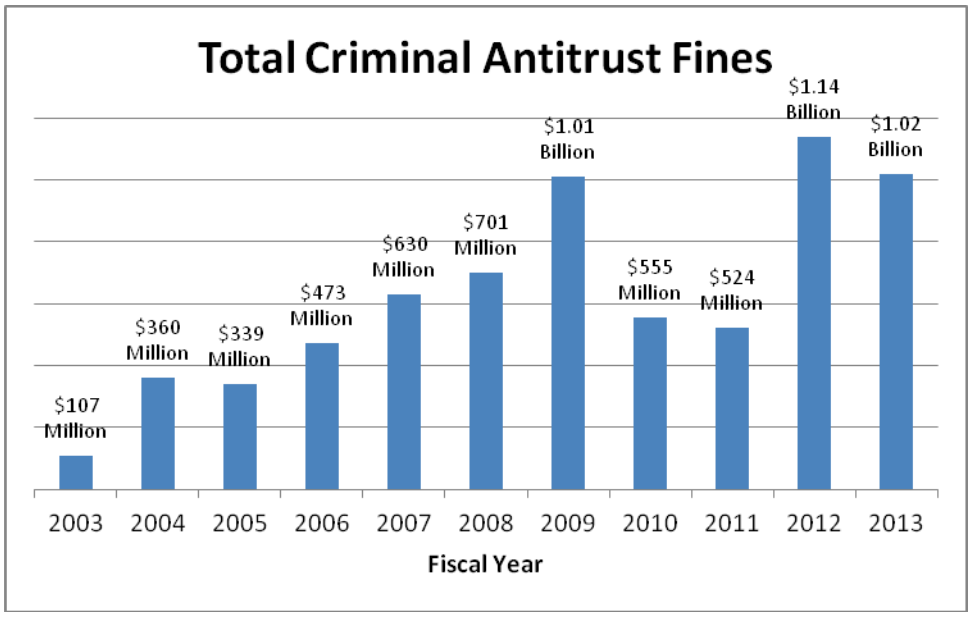
[5] This is known as the prompt-action requirement

[6] Marshall et al(2013); This would seem to indicated that firms are only applying for amnesty under the situation where there is a real threat of conviction.

parties in the case against the other cartel members.[7] This is another very important incentive of the Leniency Program. Although the company is not removed from private litigation, it is removed from the trebling of damages, which can be quite expensive, depending on the size and scope of the cartel.

The Leniency Program has been considered a tremendous success. As told by Scott D. Hammond, Director of Criminal Enforcement of the Antitrust Division at the U.S. Department of Justice in 2011; "It is, unquestionably, the single greatest investigative tool available to anti-cartel enforcers…In the last two years, cooperation from amnesty applications has resulted in scores of convictions and well over $1 billion in fines."[8] According to Hammond, the policy seems to be achieving what it set out to accomplish. As shown in Figure 1, the criminal fines from the DOJ have generally increased between 2003-2013, except for sharp drops in 2010 and 2011.

Figure 1: Total Criminal Antitrust Fines



Source: Baer and Hosko(2013)

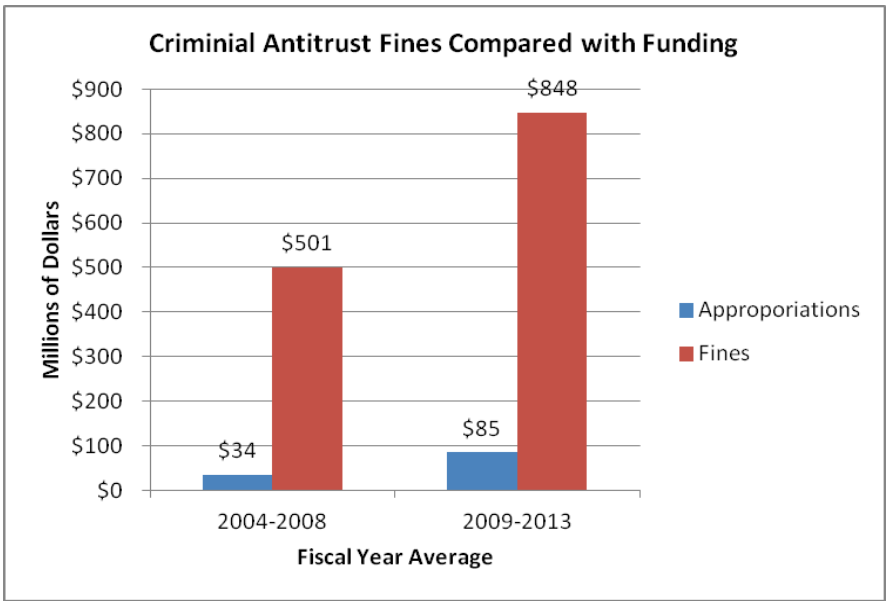
The Leniency Program has grown in scope over time, as the DOJ antitrust division partners with various other enforcement agencies, such as the FBI and foreign enforcement

[7] ibid
[8] Baer and Hosko (2013)

agencies, to help with the dissolution of cartel behavior. William J. Baer, Assistant Attorney General for the Antitrust Division, and Ronald T. Hosko, Assistant Director for Criminal Investigative Division of the FBI, testified that the combined enforcement efforts and collaboration as increased the overall effectiveness, and ability of the DOJ to bring cartels to justice. Through its "[aggressive] pursuit", the DOJ has filed 50 criminal cases, issued $1.02 billion in fines, and given 28 prison sentences averaging two years for the 2013 fiscal year.[9]

Despite having a limited budget, the DOJ has been able to exact large criminal fines on conspiratorial firms as demonstrated by the figure below. As shown in Figure 2, the returns were, on average, almost $15 million in fines for every $1 million appropriated from 2004-2008, and $10 million in fines for every $1 million appropriated from 2009-2013.

Figure 2: Criminal Antitrust Fines Compared with Funding



Source: Baer and Hosko(2013)

[9] Baer and Hosko (2013), pg. 2

1.2.1: Controversial Policy Stipulations

Some papers have raised the question whether or not the major stipulations to receive leniency are effective. Stipulations 1 and 2, the prompt-action requirement and previous information clause might have unintended consequences. Over the next two sections, I will examine some of the general thoughts regarding these policy stipulations to get a better grasp on the pros and cons of each stipulation. I will seek to offer some recommendations regarding these stipulations after setting up my model of collusion, and the game between the firms.

1.2.2: The Prompt-Action Requirement

A firm must take prompt-action to end its involvement in the cartel and inform the DOJ that a cartel exists in order to be eligible for leniency. The firm's "clock" to turn themselves in and be eligible for leniency begins when the firm's legal counsel learns of the illegal activities.[10] However, while a company does know that it must report quickly to the DOJ to be eligible for amnesty, how quickly remains the question. Prompt-action is loosely defined and there is not a specific timeline for when a firm must report its actions, which leaves the firm open to risk as the interpretation of "prompt" falls entirely on the DOJ.

Leslie (2006) argues that the prompt action requirement creates a disincentive for firms to come forward as it introduces uncertainty. Essentially, firms do not know whether or not they will receive leniency once they apply, because the DOJ might determine that their reporting may not have been prompt. This uncertainty could be enough to dissuade a firm from applying, especially if it feels that the DOJ does not have enough information to prosecute on its own. Leslie (2006) also argues that the prompt-action requirement can increase trust amongst the firms involved in

[10] Leslie (2006)

the cartel. After an extended period of time, firms may feel that they are no longer eligible for leniency, and therefore do not have to worry about any firm applying for it. For example, if "prompt-action" were roughly defined as within three years of a cartel's formation, then for the first three years firms would have to worry if another company would apply for leniency. However, after three years, if firms know they are no longer eligible, then there is no incentive for any firm to come forward to the DOJ. The only way for the cartel to be broken up is if the DOJ builds the case itself.

1.2.3: Previous Information Clause

As stated by the Leniency Program, in order for a firm to be eligible to apply for leniency, the DOJ must not have any prior knowledge regarding the cartel's existence, and it cannot currently be engaged in an investigation. On the surface, this seems to make sense as once an investigation has begun, why would the DOJ want to reward a company for coming forward once it is being investigated; the goal of the policy is for cartels to come forward early, and not wait until the DOJ has started an investigation. However, the "previous information" clause may have some unintended consequences.

The first problem before examining this stipulation is trying to define what information means to the DOJ. Just having information or investigating firms does not guarantee that the DOJ will be able to secure a conviction or settlement from the parties. A corroborating witness could certainly help make conviction more likely. Also, by not allowing firms to apply for leniency while the DOJ has information, the DOJ is essentially creating "trust" amongst the firms; once they all know that the DOJ has some information about their cartel, they know that no firm will

come forward, since there is not an incentive to do so.[11] As discussed before, the DOJ wants to be creating distrust amongst the firms to help with the destabilization.

The DOJ has eased their stance on this stipulation through its introduction of Type B Amnesty; here the firms are still able to receive leniency even if the DOJ does have prior information. It appears the introduction of Type B Amnesty has been effective as 80-90% of leniency applicants fall under this category. However, an unintended consequence of the Leniency Program is that firms may be creating smaller, sacrificial cartels to distract the DOJ.

One of the main concerns that have been voiced by various authors with the Leniency Program is that with the growing number of leniency applicants the DOJ will only be focusing on prosecuting cases that have been brought to them by the program. In turn, the DOJ might not be devoting resources to discovering cartels that have not applied to the Leniency Program. Marshall et al(2013) allude to this idea in their examination of multi-product markets. Firms may be creating smaller sacrificial cartels to keep the DOJ busy and shield the larger, and more profitable, cartelized industries. Firms could optimize by "creating" smaller cartels and applying for leniency with the DOJ to keep them investigating these smaller cases. Easing the stipulation about previous information may allow the DOJ to prosecute cases quicker because they have a corroborating witness, and thus save its limited resources to devote to investigation. However, it may come with more leniency applicants that could be blocking the DOJ from larger, and more impactful, cartels.

[11] This idea is similar to the one proposed by Leslie (2006) in relation to the prompt-action requirement.

1.3: The Pre-emption and Prosecution Effects

The policy laid out by the DOJ is attempting to change the cost-benefit analysis of the firms, and therefore change the incentive structure that they face. The DOJ is attempting to tip the scale in favor of applying for leniency, and thus revealing information about a cartel. If firms fear the government will soon begin prosecution, they may be more inclined to apply for amnesty. If all firms have the same information about the DOJ, they all know that the other firms have a strong incentive to apply as well. This creates an additional incentive to beat the other firms to apply to avoid being left out. This issue highlights two of the important incentives – the prosecution and pre-emption effects – that need to be examined to understand the policy underlying the policy that need to be examined to under stand the policy.[12]

The prosecution effect drives a firm to seek leniency if it fears the DOJ could investigate and prosecuted the cartel, so it would want to secure the potential fine reduction by applying. The prosecution effect in this model will take on the form of the probabilities of investigation and conviction. These probabilities will be discussed in greater detail in the subsequent section examining the existing literature.

The pre-emption effect is the idea that a firm will seek amnesty if it fears one of the other colluding firms might apply for leniency. Motchenkova(2004) believes that this effect is the main determinant on whether or not the Leniency Program is successful. The incentive to pre-empt is driven by the leniency provision that allows only one applicant to receive leniency for a given product. There is a "multiplier effect" between the prosecution and pre-emption effects.[13] As the prosecution effect increases, driven by an increase in the probability of investigation and conviction, firms are more likely to want to apply for leniency. If both firms are aware of the increase, then both know that the other firm will be more interested in applying for leniency. As

[12] These effects were proposed and examined by Harrington (2011)
[13] Harrington (2011)

a result, a firm will more likely apply for leniency faster, given that the other firm is facing the same choices.

Leslie (2006) discusses the same issue by looking at the role of distrust in the market and refers to this as the incentive to defect. The incentive to defect is based off of the expected returns from defecting, the reduction in fines and avoidance of prison time, and knowing that the leniency is on the table for all cartel members. Leslie(2006) discusses a "vicious cycle" of distrust, where "as it becomes more rational or beneficial for one's partner to confess, one should trust her less," and then "once she knows that he trusts her less, than that should make her trust him even less."[14] The key is getting the cartel members into this cycle in order to maximize distrust with the industry.

[14] Leslie(2006), pg. 474

Chapter 2

Literature Review

The literature surrounding the Leniency Program has examined what might the optimal leniency policy be under varying situations, perverse incentives that may be hidden within the policy, and how firms may be optimizing given that they are facing this policy. A common conclusion from many of the papers is that the Leniency Program may destabilize cartels as they can now fail from firms applying for leniency, as well as cheating on the agreements.[15] However, there can be some underlying perverse incentives. Marshal et al (2013) show that colluding firms may create smaller sacrificial cartels to help insulate the larger cartel from investigation as the DOJ is preoccupied with prosecuting the cases brought through the Leniency Program. Overall, the analysis of the policy and its effects "hinge on specific parameters" and those values "are unknowable theoretically and difficult to estimate empirically."[16]

Before setting up the model and the game played by the firms, I will clarify the meaning of the probabilities of investigation and conviction by synthesizing some of the prevailing literature. The understanding that these probabilities are separate and increasing over time is key to the conclusions and results put forward by this paper.

[15] This is noted by Miller (2009)
[16] Miller (2009), pg. 751

2.1 The probability of Investigation and Conviction

Assuming firms are rational members of a cartel, they will be constantly weighing the costs and benefits of remaining in the cartel. One-consideration firms must take into account when weighing these calculations is the chance they will be investigated and prosecuted by the DOJ. As discussed earlier, if firms feel they might be investigated soon, they might use the Leniency Program to protect themselves; this is the prosecution effect. If firms feel that other firms might use the Leniency Program, they will try to take advantage of it first; this is the pre-emption effect. The probabilities of investigation and conviction play two important roles as they are the fundamental drivers of the prosecution effect, which in turn causes firms to react because of the pre-emption effect.

The first step in examining these probabilities is clearly defining their meaning, and examining how previous works have interpreted these probabilities. The names may differ - the rate of law enforcement (Motchenkova, 2004), probability of audit (Aubert et al, 2006), conviction probability (Lefoili and Roux, 2012), and the detection probability (Cai, 2012) – but the most important difference is how they treat investigation and prosecution. Motchenokva (2004), Motchenkova and van der Lann (2011), Lefouili and Roux (2012), and Aubert et al (2006) all make the same underlying assumption: the probability of detection and probability of conviction are one in the same. The probabilities are grouped together in the investigation and prosecution stages of the game, which can potentially be hazardous and ignore some crucial interactions.

Harrington(2005) and Motta and Polo(2003) recognize that there are two different probabilities that are working together, and they should be treated differently. Both papers

differentiate the probability of the DOJ launching an investigation, and the probability the DOJ is able to successfully convict. The probability that the DOJ launches an investigation directly relates to the amount of the information that they have on the industry and firms in question. The probability that the DOJ is able to convict depends on the strength of the DOJ's information and evidence, as well as if they have any co-operating witnesses, i.e. leniency applicants. I believe, and it will be fundamental in my analysis, it is important to treat these probabilities as different to fully explore the decision making procedure of firms and the DOJ.

The next issue regarding these probabilities of investigation and conviction, whether grouped together as one probability or differentiated, is how to effectively model them. Models by Motchenkova and van der Laan (2011), Aubert et al (2006), and Motchenkova (2004) treat them as instantaneous probabilities that are determined within one period of the game, and do not carry over to subsequent periods. Additionally, if the probability is considered to be constant over time, Harrington (2005) acknowledges that is a "strong and restrictive assumption".[17] He points to the fact that some of these papers conclude that a cartel will never use the Leniency Program. If the value is fixed, and that value determines whether or not a firm will apply for leniency, then if it is not optimal in one period to apply for leniency, it will never be optimal in the future periods. Aubert et al (2006) treat the "audit probability" as constant over time and history, and recognize this is a largely unrealistic assumption.[18]

Motta and Polo (2003) did allow for the probability of investigation to change over time by allowing it to take the values of 0 and α. However, while I believe this contribution by Motta and Polo helps to push the focus in the right direction, it falls short of illustrating how I believe this probability should be considered. I argue that the probability the DOJ investigates a given industry would increase over time. Quite simply, while other models treat information as either

[17] Harrington(2005), pg 2

[18] They made the assumption with the idea of simplifying the problem so they can focus on the role of rewards.

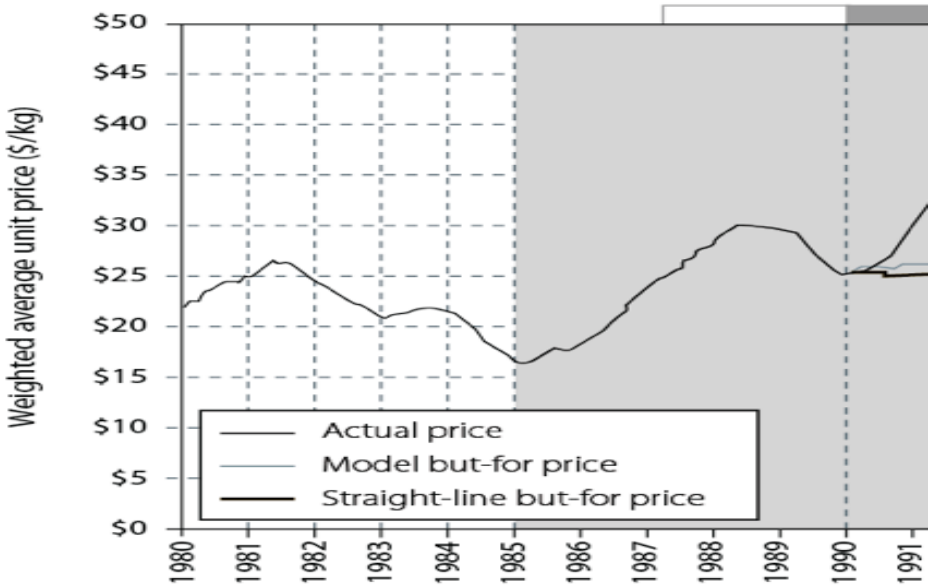
used or forgotten after a given period, like Aubert et al (2006), the DOJ is able to store information, and build upon it in each subsequent period. As time goes on, the probability of investigation and prosecution will increase over time. I base this argument on thinking about the problem logically, and because of an underlying hidden incentive with the policy.

Before explaining my reasoning, I wish to clarify an interplay with the probabilities of investigation and conviction. Assuming that the probability of investigation rises with the level of information the DOJ has on a given industry, then it is reasonable to assume that the probability of conviction would increase as well. The probability of conviction is dependant on the information and evidence that the DOJ has, so an increase in evidence would likely lead to an increase in the conviction rate. Of course, there can be errors in how the case is handled and prosecuted, but for this analysis I will not be as concerned with these types of errors.

So in regards to the probability of investigation, and thinking about what a cartel does logically, it is easier to understand why over time a cartel is more likely to be detected. As discussed earlier, a cartel raises prices above what the expected market prices should be. Over a small period of time, a price increase might not look like much. There are plenty of factors that could contribute to short-term fluctuations in prices such as a change in costs, technology, and tastes among others. However, as more and more time passes, and prices remain above expectations, the DOJ may have their eye turned toward the industry. How is the higher price being maintained in a market when forces may be pushing the pricing in an opposite direction?

I will use a simple pricing graph from a vitamin price fixing cartel to illustrate what I am describing. The vitamin price fixing cartel lasted from 1985 until 1999, and had one of the largest fines ever imposed in a price-fixing case.

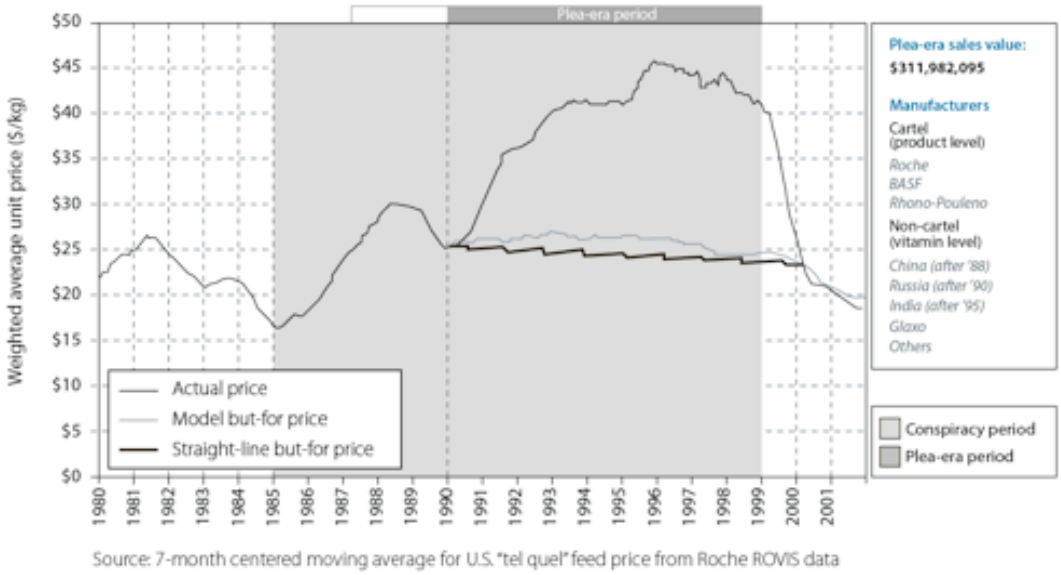
Figure 3: Vitamin Price Fixing Cartel 1980-1991



Source: Marshall and Marx (2012)

Figure 3 looks at the actual price of Vitamin A Acetate, one of the vitamins price fixed during the cartel. The actual price is slightly above, and increasing, over the but-for prices. For this example, the but-for prices, meaning the price but-for the conspiracy, will serve to represent the expected market price. This graph shows prices are increasing, but not necessarily anything illegal has happened; the DOJ might not be immediately attracted to investigate the vitamin industry. Figure 4 illustrates how the conspiracy played out over the entire time from 1985 until 1999.

Figure 4: Vitamin Price Fixing Cartel 1980-2001



Source: Marshall and Marx(2012)

The actual price continued to stay well above the but-for expected price and over this longer period of time, the DOJ may then open an investigation into an industry. While you cannot say definitively that there is something illegal going on in the market, it is plausible that this could alert the DOJ to investigate.

Looking at prices could just be one piece of the puzzle in determining if a cartel is operating within a market. However, the DOJ does not just "forget" evidence after one period. It can continue to build on the pre-existing information that it already has. As it acquires additional information, it is reasonable to assume that they may be able to connect a few more pieces of the evidence together. So with an increased time horizon, the DOJ is able to see more of the picture and build off of evidence that it already has collected.

As discussed, an increase in the probability of investigation increases the probability of conviction. The probability of conviction will also increase for another reason as well because of a hidden incentive within the Leniency Program. Aubert et al (2006) showed that the existence of a rewards program increases the likelihood that a firm will keep evidence of its collusive

behavior. If a firm thinks it will want to apply for leniency in the future, it will want to be able to offer the DOJ strong evidence to support its application. The more they can give the DOJ, the more likely they will be to receive the reduced fines. If firms are keeping better evidence of their communication and agreements, it is certainly likely that the DOJ will have an easier time building the case against the colluding firms.

While previous works have treated the probabilities as combined, constant over time, or instantaneous, I have argued and shown that these probabilities should be considered separate and increasing over time. Considering these probabilities as I have presented will be fundamental in the framework of my model, and critical in understanding the results and my recommendations.

Chapter 3

The Model

The model of my collusive payoffs is based off of Motta and Polo (2003). Their model already incorporated my fundamental requirement by differentiating the probabilities of investigation and conviction. The model I present is almost exactly the same, with a few differences that will be discussed as I prevent my value of collusion equation. The major difference is the understanding of the probability of investigation and conviction. Motta and Polo(2003) allowed the probability to take on different values, but was only generated for one period only. My understanding of those probabilities is that they increase over time, and continue to build up from period to period. While the different understanding does not necessarily reflect itself in the form of the equation, my conclusions are driven by the understanding that the values are increasing over time. Over the rest of this chapter, I will discuss my value of collusion equation, and then move on to examining the strategies the firms can choose when engaging in collusion.

3.1: Value of Collusion

My value of collusion constraint (V_C) is a function of four enforcement choices by the DOJ, and the profits the firm expects to receive from collusion and competition. The DOJ is able to choose four enforcement parameters with its limited budget (limited in the sense that it is not infinite) that helps in aiding cartel desistance. The enforcement choices are observable by the firms after the DOJ has set them at the beginning of the game.

$$V_C = \alpha p(\pi_N - \delta F) + \alpha(1-p)(\pi_N) + (1- \alpha)\pi_M$$

- The level of fines: F = [0, F^1], for firms that are found guilty of collusion. F is exogenous to the model, and is based on the size and scope of the cartel in question.
- The percentage reduction of fines: δ = [0,1], that a firm is eligible to receive if the firm participates in the Leniency Program.
- The probability of investigation: α = [0,1], and is increasing over time.
- The probability of conviction: p = [0,1], that firms are successfully prosecuted by the DOJ when they do not receive any help from a participating firm, i.e. a Leniency applicant. This probability is also increasing over time.

The last two variables, π_N and π_M, represent the profits from competition and profits from collusion, respectively. The profits from collusion are monopoly profits, hence the notation π_M. It is assumed that $\pi_M > \pi_N$ because achieving monopoly profits is greater than the profits from gained from competition amongst the firms.

The first major difference in my model and the model put forward by Motta and Polo (2003) is the treatment of the probability of investigation. Motta and Polo(2003) made the assumption that the DOJ is only able to keep evidence and use it in the current period. I believe this assumption constrains the analysis, as the DOJ is able to store evidence, and it compounds over time. My understanding of the probability of investigation is similar to the understanding put forward by Cai (2012).

Cai (2012) claims that the probability of investigation is equal to $B/(B+k)$, where the probability of investigation takes into account two factors, B and k. B is an anti-trust index meant to model its enforcement efforts. The other variable k is meant to account for the natural barriers that the DOJ faces when investigating the cartel. These natural barriers could be things such as multi-national corporations and the amount of cooperation between anti-trust agencies in various

countries. Cai(2012) views this *k* as a decreasing function over time, and I agree. Additionally, I think the understanding of *k* can change to account for my assumption that the DOJ is able to store information. This "learning" dynamic also would cause a decrease in *k*, and thus an increase in the probability of investigation. So the α in this paper takes on a similar understanding as put forward by Cai (2012).

The next subtle difference I make to my model between that of Motta and Polo (2003) is that when a firm is investigated, but not prosecuted successfully, they do not make π_M for that period. Despite the unsuccessful prosecution, I believe that firms will not continue to actively collude while they are being investigated. This will only serve to create more evidence for the DOJ to use against the firms. However, once the investigation is over, the firms return to collusion and achieving monopoly profits.

So, thinking about the V_C equation, we see that it has three parts.

(1) (2) (3)

$$\alpha p(\pi_N - \delta F) + \alpha(1-p)(\pi_N) + (1-\alpha)\pi_M$$

The first part gives the payoff if a firm is investigated and prosecuted successfully. It makes competitive profits, and has to pay a fine. The second part shows the payoff if a firm is investigated, but not prosecuted successfully. The third part shows that a firm makes monopoly profits if it is not investigated by the DOJ.

3.3: The Firms' Strategies

The first decision a firm must make is whether or not to engage in collusion, and for simplicity we will always assume that value of colluding (V_C) is greater than the value of deviating. This assumption will allow us to focus on the mechanisms that will induce a firm to decide on whether or not it will apply for leniency. Therefore, the firms face two different

strategies: collude and reveal (CR) and collude and not reveal (CNR). We will now examine the value constraints placed by these two strategies before moving on to the game between two firms.

3.3.1: Collude and Reveal (CR)

Under the situation where the firm reveals its involvement to the DOJ, we generate our new value constraint, V_{CR}. The changes from V_C to V_{CR} are simple, with the probability of conviction, *p*, equal to one. With a leniency applicant, the firm has admitted its guilt and therefore will be found guilty. I make the additional assumption that *p* will be the same value for all firms involved in the cartel; with one witness helping the DOJ, they will be better equipped to prosecute the other firms involved. Additionally, the final assumption from Motta and Polo (2003) is that the DOJ will not make any prosecution errors that could lessen *p*. The resulting value constraint of the CR strategy is the following:

$$V_{CR} = \alpha(\pi_N - \delta F) + (1- \alpha)\pi_M$$

3.3.2: Collude and Never Reveal (CNR)

Under the situation where the firm chooses not to reveal when they are investigated, the new value constraint V_{CNR} is equal to V_C with the exception of one minor change. When firms do not reveal, they are not eligible for a discounted fine, so δ will drop from the equation. Thus our V_{CNR} is the following:

$$V_{CNR} = \alpha p(\pi_N - F) + \alpha(1-p)(\pi_N) + (1- \alpha)\pi_M$$

The burden of successfully investigating and prosecuting the cartel is now entirely on the DOJ and the outcome is determined by the DOJ's enforcement efforts.

3.3.3: CR versus CNR

When examining these two value constraints, the DOJ obviously would prefer that V_{CR} dominates V_{CNR}, that is $V_{CR} > V_{CNR}$, for two reasons. First, when a firm applies for leniency, the DOJ has an easier time prosecuting the case as it now has a corroborating witness and this could reduce the prosecution costs and length of trial. Second, the DOJ wants to create distrust within the industry. As discussed earlier, cartels are stable as long as there is sufficient trust and profits gained from collusion. As distrust grows amongst firms, the stability of collusive agreements is more likely to fall. So, setting the inequality $V_{CR} > V_{CNR}$ the first condition of an effective policy revels itself.

$$\alpha(\pi_N - \delta F) + (1- \alpha)\pi_M \;>\; \alpha p(\pi_N - F) + \alpha(1-p)(\pi_N) + (1- \alpha)\pi_M$$

$$p > \delta \text{ [19]}$$

This is a rather straightforward principal to understand, but still worth discussing under the framework of my model. It would not make sense for the DOJ to only offer a slight fine reduction, say 10% ($\delta = 0.9$), if there is only a 50% ($p = 0.5$) probability of conviction. Firms need to be enticed to apply for leniency, and doing so would most likely require a significant fine reduction. As p increases over time, the DOJ can decrease the level of fine reductions a firm might receive (an increasing value of δ). This understanding shows that DOJ can offer reduced leniency over time, while still maintaining the balance that revealing will be preferred over not revealing.

While this appears to be the condition the DOJ needs to meet in order to guarantee that reveal is played, it alone might not be enough. The inequality certainly makes sense as discussed above, but I will show that the DOJ must take more into consideration if the firms are utilizing mixed strategies in a symmetric game. The next section of the paper will be devoted to

[19] The derivation from this equation can be found in Appendix A

examining the game played, while identifying the pure and mixed strategy Nash Equilibria. From the firms' mixed strategies, I will show the enforcement choices the DOJ needs to make in order to guarantee that firms will reveal at least a portion of the time. What will arise from the game is that the condition $p > \delta$ may not be enough, or the only way, to induce firms to reveal in a game of mixed strategies.

Chapter 4

The Game

The V_{CR} and V_{CNR} equations set the groundwork for the game. The game will be a simultaneous move game played between two symmetric firms, with both having access to the same information - the policy parameters $\{\alpha, p, \delta, F\}$. The firms will choose the strategy, reveal and not reveal, that maximizes their expected payoffs. The two-by-two game matrix is shown below.

Table 1: Game Model

		Firm 2	
		R	NR
Firm 1	R	X, X	W, Z
	NR	Z, W	Y, Y

The payoffs represented by {W, X, Y, Z} are the following values:

$$W = \alpha(\pi_N - \delta F) + (1- \alpha)\pi_M$$

W is the payoff for the firm that reveals, while the other firm has chosen to not reveal. Since the firm has confessed it will be convicted, but will receive a discounted fine

$$X = \alpha(\pi_N - ((.5+.5\delta)F)) + (1- \alpha)\pi_M$$

X is the payoff for the firm when both firms apply for leniency. To receive the fine reduction, it must be the first firm to report. As a result, the expected fine reduction that a firm receives is given by $(.5+.5\delta)F$.

$$Y = \alpha p(\pi_N - F) + \alpha(1-p)(\pi_N) + (1- \alpha)\pi_M$$

Y is the payoff where neither firm reveals, and it is equal to V_{CNR}.

$$Z = \alpha(\pi_N - F) + (1- \alpha)\pi_M$$

Lastly, Z is the payoff to the firm that did not reveal, while the other firm did reveal. They are now guaranteed to be successfully prosecuted, but will not receive any discount δ, and thus pay the full value of F.

4.1: Pure Strategies

Pure strategies give the strategy choices for each player for every situation that they will face within the game. I will look at the strategies for Firm 1 given the decisions made by Firm 2. Since the firms are symmetric, the resulting strategy choices will be the same for Firm 2.

If Firm 2 were to choose R, Firm 1 must decide between R and NR by comparing the payoffs. Firm 1 would also choose R if it was selected by Firm 2, as the payoff from choosing R is greater than the payoff from choosing NR.[20] This makes sense intuitively as Firm 1 at least has a chance of receiving a fine reduction when they reveal as opposed to not revealing.

If Firm 2 were to choose NR, Firm 1 once again decides between R and NR by comparing the payoffs. Firm 1 would choose NR in this case as well, as the payoff from choosing NR is greater than the payoff from choosing R.[21] Once again, this makes sense intuitively as Firm 1 would prefer to not reveal information if its partner will not be revealing as well, as it will result in a higher payoff.

After going through the best responses for Firm 1 to Firm 2's actions, we can determine that there are two Nash equilibria.[22] The Nash equilibria occur at (R,R) and (NR, NR) and are

[20] $\alpha(\pi_N - ((.5+.5\delta)F)) + (1- \alpha)\pi_M > \alpha(\pi_N - F) + (1- \alpha)\pi_M$

[21] $\alpha p(\pi_N - \delta F) + \alpha(1-p)(\pi_N) + (1- \alpha)\pi_M > \alpha(\pi_N - \delta F) + (1- \alpha)\pi_M$

[22] Since symmetric game, we also now know Firm 2's actions in response to Firm 1

indicated on the payoff matrix below.[23] At these points, neither firm as an incentive to change its strategy choice.

Table 2: The Game with Nash Equilibria

		Firm 2	
		R	NR
Firm 1	R	X, X	W, Z
	NR	Z, W	Y, Y

4.2: Mixed Strategies

One of the major contributions of this paper will be to look at the ramifications if the firms are playing a mixed strategy; that is, the probability that they play R is *g* and the probability that they play NR is (1-*g*). The exploration of this possibility will show that the DOJ has different enforcement choices, if it believes the firms might be using mixed strategies. The probability *g* that firms play R is determined by making the firm indifferent between the strategy choices of the other firm. Below is the payoff matrix, including the probabilities that the firms plays R.

Table 3: Game Model with Mixed Strategies

		Firm 2	
		(*g*) R	(1- *g*) NR
Firm 1	(*g*) R	X, X	W, Z
	(1- *g*) NR	Z, W	Y, Y

[23] Where (A, A) represents the strategy choices for (Firm 1, Firm 2)

So to determine *g* we will use Firm 1 as the example. To determine the value of *g*, we get the following equation:

$$(g)X + (1\text{-}g)W = (g)Z + (1\text{-}g)Y$$

On the left side of the equation, it shows the payoffs for Firm 1 choosing R, given Firm 2 chooses R with a probability *g* and chooses NR with a probability 1-*g*. On the right side of the equation, it shows the payoffs for choosing NR, given Firm 2 chooses R with a probability *g* and chooses NR with a probability 1-*g*. The value of the probability *g* that is solved for from this equation, is the probability that makes firm 1 indifferent between choosing R and NR given the strategies of Firm 2.

$$(g)X + (1\text{-}g)W = (g)Z + (1\text{-}g)Y$$

$$gX + W - gW = gZ + Y - gY$$

$$gX + gY - gW - gZ = Y - W$$

$$g = (Y - W)/(X+Y - W - Z)$$

We then substitute the equations for W, X, Y, and Z into the formula to get the resulting *g* value.

$$g = (\delta - p) / (0.5 + 0.5\delta - p)$$ [24]

In determining the probability that a firm will play R, the firm takes into account the discount it will receive, δ, and the probability that they will be convicted, *p*. If the DOJ believes the firms are going to play a mixed strategy, they will want to set a policy that guarantees R will be used a portion of the time (*g*).

[24] The derivation of this equation can be found in Appendix B

4.3: The Leniency Program Under Mixed Strategies

Given that we have now determined the probability that R will be played (g), the question now is how does the DOJ guarantee R will be played, and what is the optimal policy. The DOJ is facing the situation where it must choose to allocate funds between investigating and prosecuting, while also determining how much of the fine reductions it should be giving. I will first examine the constraints the DOJ is facing with their enforcement choices in order to make sure that g is in fact played, i.e. has a positive value. Next, I will examine the tradeoffs through a cost-value equation to determine what is in the best interest of the DOJ.

4.3.1: Constraints to Guarantee that R is Played

Looking at the equation $g = (\delta - p)/(0.5 + 0.5\delta - p)$, there are two possible ways for g to be a positive value, and therefore played by the firms: the numerator and denominator are both positive, or the numerator and denominator are both negative. We will examine both cases here to see the implications for policy choices.

For both the numerator and denominator to be positive, the following conditions must be met:

$$\text{Condition 1: } \delta > p$$

$$\text{Condition 2: } \delta > 2p - 1$$ [25]

[25] Derived from the equation $1 + 0.5\delta - p > 0$

These conditions guarantee that *g* is played with a positive probability. To understand what these conditions show, I will look at two examples, one with a high value for *p* and one with a low value for *p*, and examine the resulting implications for the DOJ's leniency choices.

I will start with the low value case and set $p = 0.2$; that is, there is only a 20% chance of successful conviction. For Condition 1 to hold, then $\delta > 0.2$. For Condition 2 to hold, $\delta > -0.6$; a negative value would indicate that firms are actually receiving a positive reward, in addition to the fine reduction. As a result, for *g* to be a positive number, $\delta > 0.2$, as this would then meet both conditions. Under our understanding that the *p* is increasing over time, this would mean that discount must decrease over time, meaning the punishment is increasing. This certainly is not an unrealistic condition if thought about logically; as the DOJ is more and more likely to be able to successfully prosecute a cartel, they do not need to be as lenient.

If $p = 0.8$, that is a high value, there is an 80% chance of successful prosecution. For condition 1to hold $\delta > 0.8$, and for condition 2 to hold $\delta > 0.6$. Therefore, $\delta > 0.8$ for both conditions to hold true, and thus make *g* a positive value. This merely goes to show, as the first low *p* value showed, that the DOJ can offer decreasing leniency over time; in fact, it has to in this situation to make sure that R is played.

This situation, where both the numerator and the denominator are positive, the DOJ is taking a harsher stance against collusion. The fine reduction will never be less than the probability of conviction, and as time goes on, leniency will decline. I will refer to this as the DOJ's punitive strategy.

The next case to guarantee R will be played with a positive probability is when both the numerator and denominator are both negative. Under this situation, you only need to flip the inequality signs from the previous case to get the new conditions that make this case true.

Condition 1: $\delta < p$

Condition 2: $\delta < 2p - 1$

Once again, we will look at the implications of having a high and low *p* value to see the implications for the value of δ.

If $p = 0.2$, then $\delta < 0.2$ would have to be true for Condition 1 to hold true. For Condition 2 to hold, $\delta < -0.6$. For *g* to become a positive number under this case, $\delta < -0.6$, which indicates the DOJ must offer a positive reward. As the DOJ has a low chance of a successful prosecution, they must offer positive rewards in order for the firms to want to take advantage of the Leniency Program, which would result in the DOJ getting a conviction of the other firms involved. The role of positive rewards will be examined in the next section.

If $p = 0.8$, then $\delta < 0.8$ for Condition 1 to hold true. Condition 2 would dictate that $\delta < 0.6$. Therefore, in order for *g* to be a positive number, $\delta < 0.6$ in order to get firms to use the reveal strategy. This situation shows us that when the DOJ has a high probability of conviction, they no longer need to offer positive rewards to induce the reveal strategy. They just need to offer sufficient leniency that is below the probability of prosecution.

Under this second case, we can think of this as the situation where the DOJ is more lenient. It has introduced us to an additional leniency solution; offering positive rewards. The question remains on when the DOJ must offer positive rewards, that is, when $\delta < 0$. Condition 2 will allow us to answer this question.

$$\delta < 2p - 1$$

$$\delta = 0, \text{ inequality becomes } 0 < 2p - 1$$

$$p > 0.5$$

This analysis shows that the DOJ must offer positive rewards if the probability of conviction is less than 50%. If the DOJ has a greater than 50% chance of conviction, they do not need to offer positive rewards. This result is not all that surprising, as firms are going to need more of an incentive, like positive rewards, if they are going to come forward and apply for leniency if their chances of being successfully convicted are low.

4.3.3: Role of Positive Rewards

In our last situation, we saw that if there is less than the 50% chance of conviction, the DOJ must offer positive rewards in order to make the players reveal at least part of the time. Aubert et al (2006) examined the role of positive rewards on cartel behavior and found that they can have a positive effect on cartel dissolution. However, their work focused on the role of positive rewards for individuals, while in this setting the rewards would be going to the firm. Aubert et al (2006) concluded the positive rewards to individuals are a strong tool to deter cartel formation. The above framework has demonstrated that positive rewards to the firm could also be effective to induce the reveal strategy.

4.3.2: The DOJ Optimization Problem

Given that the DOJ has a limited budget, it must choose how to enforce its anti-trust laws. Essentially, the DOJ must weigh the value gained from successfully prosecuting firms versus the costs of investigation and prosecution. Continuing with the mixed strategies, I will first seek to quantify the value of successful prosecutions.

The number of successful prosecutions is a result of the DOJ's independent enforcement efforts, α and *p*, and whether or not a firm applies for leniency. So the number of successful prosecutions (Q_S) is a function of the number of investigations multiplied by the probability that they are successful. Q_S takes the following form, where the number of potential investigations is equal to N.

$$Q_S = (\alpha N) \times [\, (1 - (1-g)^2) + (1-g)^2 p \,]$$

Here we can see the number of investigations launched by the DOJ is given by αN. The probability of successfully conviction is given in two parts. The first is the probability that at

least one firm reveals information to the DOJ.[26] The second is the probability that neither firms reveal information to the DOJ, so it is dependant on their enforcement effort *p*.[27] The DOJ receives value from successful prosecutions, which comes in two forms: the money received from the fines, and receives some utility now that the cartel is no longer in operation.[28] For simplicity, this value will be grouped together as V, and thus the resulting value from successful prosecutions is given by the following equation:

$$VQ_S = V(\alpha N) \times [\ (1- (1-g)^2) + (1-g)^2 p\ ]$$

The DOJ does face costs constraints since they do face a limited budget. The DOJ faces costs from launching and prosecuting cases, while also facing the cost of giving up money from fines through providing leniency. The DOJ thus faces the costs given by the following equation, where C represents cost:

$$\text{Costs} = C(\alpha N) + [(1- \delta)F \times \alpha N(1- (1-g)^2)]$$

Here the first term represents the costs of all of the investigations that the DOJ launches and prosecutes. The second term represents the loss in fine revenue the DOJ receives from granting leniency to the firms that reveal.

From these two equations, the DOJ wishes to maximize the following equation:

$$VQ_S - \text{Costs}$$

$$V(\alpha N) \times [\ (1- (1-g)^2) + (1-g)^2 p\ ] - \{C(\alpha N) + [(1- \delta)F \times \alpha N(1- (1-g)^2)]\}$$

This equation highlights that the DOJ is facing a tradeoff. It can launch a large number of investigations while offering high leniency; in this sense, the DOJ goal would be to maximize the dissolution of cartels and increasing distrust within the industry. The other choice would be for the DOJ to launch fewer investigations, and rely more on their own enforcement efforts,

[26] These would be the strategy choices (R, R), (R, NR), and (NR, R) and the regions denoted by these areas.

[27] This would be the region given by the strategy choice (NR, NR).

[28] This value could come from gains to consumers for example now that they are paying competitive prices.

specifically the probability of conviction, to break apart cartels. In this case, the DOJ would place on emphasis on bringing in fine revenue.

The significance of this equation is that it serves to highlight the DOJ can not just offer full leniency all the time as it may not be optimal for the DOJ to always offer leniency. In the situation where the DOJ has a high probability of conviction, it may not be optimal to offer full leniency as the resulting loss from fine revenues may be greater than the value they receive successful prosecution. There is a tradeoff, so it is not always optimal to say that the DOJ should grant leniency to guarantee that $p = 1$, as there is a cost to doing so. What it comes down to is whether or not the DOJ wants to maximize fine revenue, or maximize the dissolution of cartels.

Chapter 5

Conclusions and Recommendations

The main problem this paper addressed is how the DOJ Leniency Program functions in an environment of mixed strategies, given an increasing probability of investigation and prosecution. First, the paper addressed some of the discrepancies in the literature and modeling regarding the probabilities of investigation and conviction. I have made the case that these probabilities should be considered separate, and increasing over time. Second, this paper showed the DOJ can use two strategies, punitive and lenient, in regards to offering fine reductions given a game where colluding firms are using mixed strategies, while highlighting positive rewards may be required. Previous papers have shown that is always optimal to offer full leniency, but as my work as shown, the DOJ can be punitive. It could be potentially optimal for the DOJ to be strict, given its optimization problem. I will expand on this idea with my subsequent recommendations. Lastly, this paper examines the optimization problem that the DOJ faces in regards to setting its enforcement choices; while it may seem optimal to always get firms to reveal through leniency, the loss in fine revenue might exceed the gains saved in prosecution costs. The problem lies on what the DOJ values more; the destabilization of cartels or the maximization of fine revenue. Previous work has not acknowledged the DOJ optimization problem to the extent that I have; specifically, the notion that offering leniency is a cost introduces a new aspect to the analysis. Given what my modeling has shown, I will now seek to make recommendations to the DOJ regarding the Leniency Program's controversial stipulations.

The prompt-action requirement requires the firms take "prompt action" to alert the DOJ of their involvement in a cartel. There is no formal definition of what time period qualifies as

prompt, thus leaving the interpretation entirely up to the DOJ. While Leslie(2006) made the argument that this policy stipulation hurts the DOJ enforcement efforts as it adds uncertainty and can increase the trust amongst cartel members after the period has expired, I would argue that the prompt-action requirement could be a useful tool to help break apart cartels by providing for an incentive for firms to defect in earlier periods of cartel formation. By having the prompt-action requirement, it will help to maximize distrust in the earlier periods of the cartel.

Leslie(2004) argues that distrust is at its highest during the early stages of cartel as the firms are just beginning to collude. At the beginning, firms are just beginning to work together, assuming they have not previously colluded, or they are not currently colluding on another product, and have to worry about trust in two regards to their partner. A firm must worry whether or not its partner(s) will cheat on the price, or if they will tell the antitrust authorities about their cartel.[29]

As time progresses and the cartel becomes increasingly effective, the firms could potentially be making very high profits. This could create a strong incentive not to defect or apply for leniency, as the profits may outweigh the future costs. The firms are making more money than they would be if they were competing with each, but how much more is largely dependent on how successful the cartel is at colluding. I believe it would be effective to help provide the right incentives for the firms to deviate in the earlier periods so firms do not realize the full potential of the cartel.

Given my argument that probability of detection and conviction are increasing over time, my model has shown that the DOJ can offer reduced leniency over time, while still maintaining that revealing will be the preferred choice to not revealing. It is actually required for the fine reduction to decrease over time if the DOJ were to follow the punitive strategy. The DOJ could

[29] Leslie (2004)

offer full fine reductions for a given period, which they would qualify as prompt. However, after this period as passed, firms could still be offered a partial fine reduction. This could help add to the distrust in the earlier periods, while still maintaining the distrust after the prompt period has passed.

The other controversial policy stipulation relates to the DOJ's previous information clause. As discussed in the DOJ's optimization problem, there is a tradeoff that the DOJ has to make, and the previous information clause is directly tied to this. The DOJ could allow firms to apply for leniency even if they already have information on the cartel. As I have shown, the probabilities of investigation and conviction are separate. While the DOJ may have enough information to launch an investigation, it may not have enough information to convict. Therefore the DOJ could allow firms to apply for leniency, despite having previous information, and increase the likelihood of conviction, while saving time and resources.

Harrington (2005) and Motta and Polo (2003) have shown that it can be optimal to grant leniency in cases where the DOJ may already have information. Harrington (2005) demonstrated that while the initial provision is optimal, it can be quite desirable to award leniency even when the probability of conviction is high. This only serves to help reduce the stability of the cartel, and help to create distrust within the industry. Motta and Polo (2003) further backed up the work of Harrington (2005) as they too demonstrated that it is desirable to offer leniency in both settings of no and partial information.

However, as we discussed in the optimization problem of the DOJ, granting leniency coincides with reducing fine revenue. So once again the DOJ faces the question on whether or not the goal is decreasing stability of cartel agreements, or maximizing fine revenue. If the DOJ's goal is to decrease stability, then they should allow for cartels to apply for leniency despite having previous information. If the DOJ's goal is to maximize fine revenue, then they need to

weigh the loss in fine revenue versus the savings in costs they receive from the probability of conviction now being one, and therefore conviction being certain.

While this paper has served to help synthesize the existing literature, there is still work left to be done when examining the DOJ Leniency Program and how it affects the incentive structures of colluding firms. An extension of this paper would be to look at how this policy affects asymmetric firms, which would make the analysis more complex than the assumed symmetric environment. None the less, this paper has demonstrated that the DOJ has two policy choices in a game of mixed strategies. It can choose the harsher punitive strategy, or it can choose a more lenient strategy, which includes a role for positive rewards. The Leniency Program certainly has been a powerful tool in helping the DOJ prosecute cartels, but as time goes on, firms adapt. As firms adapt, it is important to understand the underlying mechanisms and incentives of the policy in order to maximize its effectiveness.

Appendix A

Derivation of $V_{CR} > V_{CNR}$

$$\alpha(\pi_N - \delta F) + (1- \alpha)\pi_M \;>\; \alpha p(\pi_N - F) + \alpha(1-p)(\pi_N) + (1- \alpha)\pi_M$$

$$\alpha\pi_N - \alpha\delta F + \pi_M - \alpha\pi_M \;>\; \alpha p\pi_N - \alpha pF + \alpha\pi_N - \alpha p\pi_N + \pi_M - \alpha\pi_M$$

$$\alpha\pi_N - \alpha\delta F + \pi_M - \alpha\pi_M \;>\; - \alpha pF + \alpha\pi_N + \pi_M - \alpha\pi_M$$

$$- \alpha\delta F \;>\; - \alpha pF$$

$$- \alpha F(\delta) \;>\; - \alpha F(p)$$

$$\delta < p$$

Appendix B

Derivation of *g*

$$g = (Y\text{-}W) / (Y\text{-}W+X\text{-}Z)$$

$$Y - W = \alpha p\pi_N - \alpha p\delta F + \alpha\pi_N - \alpha p\pi_N + \pi_M - \alpha\pi_M - [\alpha\pi_N - \alpha\delta F + \pi_M - \alpha\pi_M]$$

$$Y - W = \alpha\delta F - \alpha pF$$

$$X - Z = \alpha\pi_N - 0.5\delta F - 0.5F + \pi_M - \alpha\pi_M - [\alpha\pi_N - \alpha F + \pi_M - \alpha\pi_M]$$

$$X - Z = 0.5\alpha F - 0.5\delta F$$

$$g = [\alpha\delta F - \alpha pF] / [\alpha\delta F - \alpha pF + 0.5\alpha F - 0.5\alpha\delta F]$$

$$g = [\alpha F(\delta - p)] / [\alpha F(\delta - p + 0.5 - 0.5\delta)]$$

$$g = (\delta - p) / (0.5 + 0.5\delta - p)$$

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- Presented by the Star and Crescent Foundation to a member of the Kappa Sigma Fraternity for leadership

Al Rockwell Scholarship **Spring 2013**

- Presented by the Star and Crescent Foundation to a member of the Kappa Sigma Fraternity for outstanding leadership and academics