LUCAS CAMPIO PINHA

THREE ESSAYS ON ANTITRUST POLICIES

Tese apresentada à Universidade Federal de Viçosa, como parte das exigências do Programa de Pós-Graduação em Economia Aplicada, para obtenção do título de *Doctor Scientiae*.

VIÇOSA
MINAS GERAIS - BRASIL
2018

Ficha catalográfica preparada pela Biblioteca Central da Universidade Federal de Viçosa - Câmpus Viçosa

T
P654t
2018

Pinha, Lucas Campio, 1989-
Three essays on antitrust policies / Lucas Campio Pinha. – Viçosa, MG, 2018.
v, 80 f. : il. ; 29 cm.

Texto em inglês.
Inclui apêndices.
Orientador: Marcelo José Braga.
Tese (doutorado) - Universidade Federal de Viçosa.
Inclui bibliografia.

1. Cartéis. 2. Trustes industriais. 3. Programa de Leniência (Brasil). 4. Direito de antitruste. I. Universidade Federal de Viçosa. Departamento de Economia Rural. Programa de Pós-Graduação em Economia Aplicada. II. Título.

CDD 22. ed. 338.87

LUCAS CAMPIO PINHA

THREE ESSAYS ON ANTITRUST POLICIES

Tese apresentada à Universidade Federal de Viçosa, como parte das exigências do Programa de Pós-Graduação em Economia Aplicada, para obtenção do título de *Doctor Scientiae*.

APROVADA: 27 de fevereiro de 2018.

Bladimir Carrillo Bermudez

Silvinha Pinto Vasconcelos

Paulo Furquim de Azevedo

Renato Dias de Brito Gomes

Marcelo José Braga
(Orientador)

AGRADECIMENTOS

Aos meus pais Moysés e Maria, pelos ensinamentos e incentivos em todos os momentos da minha vida.

À minha irmã Luisa, pela consideração e carinho.

À minha esposa Taís, presente em todos os momentos com carinho, amor, companheirismo e apoio nas minhas empreitadas.

Aos meus familiares.

Aos amigos presentes na minha caminhada.

À FAPEMIG pela oportunidade do doutorado sanduíche.

À *Toulouse School of Economics* pela oportunidade e pelo imensurável aprendizado, em especial ao Prof. Renato Gomes.

Aos professores e funcionários do Departamento de Economia Rural da Universidade Federal de Viçosa, em especial ao meu orientador Prof. Marcelo Braga.

Aos meus companheiros de Doutorado, em especial ao meu amigo Guilherme Travassos.

SUMMARY

ABSTRACT

PINHA, Lucas Campio, D.Sc., Universidade Federal de Viçosa, February, 2018. **Three essays on antitrust policies**. Advisor: Marcelo José Braga.

This thesis presents three essays on antitrust policies against cartels. The first one is focused on the interplay between public and private antitrust enforcement in Brazil. The main objective is analyzing the best policies for leniency applicants related to the damage liability and disclosure of information in Brazil. We propose a theoretical game based on the Brazilian framework regarding fine setting, recidivism, among other aspects. The main conclusion is that it is optimal to grant immunity to the leniency applicant, as well as increase as much as possible the antitrust enforcement for damage claims. The three extensions confirm the following: the immunity is even more effective when there is risk of betrayal; the immunity is the best policy in the case of *ex-post* leniency; the immunity is the optimal policy when there is no bankruptcy, otherwise the applicant liability should be the minimum necessary to avoid the bankruptcy and to guarantee the refund to plaintiffs. The second paper aims at answering the following question: is the antitrust enforcement against cartels more effective when products are more homogeneous or differentiated? Based on a standard Bertrand duopoly, we concluded that the antitrust enforcement is more effective in constraining the collusive price when products are more homogeneous, although the total deterrence of all cartels occurs at the same point. In the third paper we evaluate the Brazilian Leniency Program effectiveness based on theoretical predictions on the hazard of dissolution of cartels. The hypothesis is that an effective antitrust policy that increases the rate of cartel detection raises the hazard of dissolution of cartels in the long-run, which is consistent to the policy destabilizing capacities. We rely on the survival analysis and hazard functions to estimate the empirical model. The main result is that the Brazilian Leniency Program is effective in increasing the hazard of dissolution of cartels in the long-run. Through this thesis, we intend to contribute to the literature by understanding how the incentives to collude are changed as antitrust policies are implemented in Brazil and abroad.

RESUMO

PINHA, Lucas Campio, D.Sc., Universidade Federal de Viçosa, fevereiro de 2018. **Três ensaios sobre políticas antitruste**. Orientador: Marcelo José Braga.

A presente tese é composta de três ensaios sobre políticas antitruste de combate aos carteis. O primeiro ensaio é focado na interação entre o *enforcement* antitruste público e privado no Brasil. O objetivo principal é analisar as políticas ótimas para assinantes do acordo de leniência com relação à responsabilidade pelos danos e à divulgação de informação sobre o cartel no Brasil. É proposto um jogo com base no cenário brasileiro com relação à aplicação de multas, reincidência, entre outros aspectos. A conclusão principal é que é ótimo oferecer imunidade ao assinante do acordo, bem como elevar ao máximo o *enforcement* antitruste para ações de restituição por danos. As três extensões confirmam o seguinte: a imunidade é ainda mais efetiva quando há risco de traição; a imunidade é a política ótima no caso da leniência *ex-post*; a imunidade é a política ótima quando não há risco de falência, caso contrário o assinante do acordo deveria ser responsável pelo mínimo necessário para evitar a falência e garantir a restituição dos demandantes. O segundo artigo visa responder à seguinte pergunta: o *enforcement* antitruste contra carteis é mais eficaz quando os produtos são mais homogêneos ou diferenciados? Com base em um duopólio de Bertrand, conclui-se que a maior eficácia em restringir o preço de cartel ocorre quando os produtos são mais homogêneos, apesar da dissuasão total de todos os carteis ocorrer no mesmo ponto. O terceiro artigo visa verificar a efetividade do Programa de Leniência brasileiro com base em pressuposições teóricas sobre o risco de dissolução dos carteis. A hipótese é de que uma política antitruste eficiente no sentido de elevar a taxa de detecção de carteis eleva o risco de dissolução dos carteis no longo prazo, o que é consistente com a capacidade desestabilizadora da política. O modelo empírico é estimado com base nas análises de sobrevivência e nas funções de risco associadas. O resultado principal é que o Programa de Leniência brasileiro é eficaz em elevar o risco de dissolução dos carteis no longo prazo. A intenção com a presente tese é contribuir com a literatura fornecendo evidências sobre como os incentivos à cartelização são modificados quando políticas antitruste são implementadas no Brasil e no mundo.

BACKGROUND

Since the establishment of market economy some issues related to competitiveness and market concentration emerged. More specifically, people started to notice that in monopolies/concentrated oligopolies the firms are able to take some actions that may be harmful to consumers and to competitiveness itself. Antitrust policies aim at promoting fair and legal competition in a jurisdiction (country, region and so on).

The United Stated of America (USA) was one of the first nations to enact a federal law to punish and control anti-competitiveness practices, the well-known *Sherman Antitrust Act* of 1890. The main objective was to control and punish the industrial monopolies and oligopolies that were acting coordinately at that time. Basically, the law has prevented the formation of *trusts*, as were denoted the cartels formerly. After that, the antitrust law in the USA have been improved over time and other countries started to implement their own laws. Nowadays, possibly all developed and/or democratic countries have antitrust laws and regulation.

Roughly speaking, it is possible to divide the antitrust enforcement regarding anticompetitive practices in two groups. The first one is the control of mergers and acquisitions. Mergers/acquisitions result in market concentration (which tends to increase the price), but on the other hand they may increase the efficiency (tending to decrease the price). There is a whole legal and economic literature in both streams, and basically the antitrust authority analyzes the possible consequences of allowing the operation or not (or permit with restrictions). The second activity is the punishment of anti-competitive practices, which basically includes the abuse of dominant position and collusions. A monopoly/concentrated oligopoly is not an infringement *per se*, but an abuse of dominant position generally is, such as entry barriers creation, predatory prices[1] (prices artificially low to discourage possible rivals) and price discrimination (when the company offers very similar products or the same product at different prices to extract the consumer surplus).

A collusion (or cartel) occurs when firms act coordinately to restrict the competition in a market, including agreement on prices, quantities, market division and

[1] This practice is more common in an international trade context, denoted by *dumping*.

so on. It is common to denote this type of conduct as a *hardcore* or *explicit cartel*[2], where the coordination is evident. From the efficiency viewpoint a collusion tends to reduce the allocative efficiency by increasing the price and decreasing the quantity sold. Like a monopoly, there is an increase of producer surplus, a reduction of consumer surplus and is created or enlarged the deadweight loss. From the consumer point of view the cartel effects are even worse: there is a transfer of consumer surplus to the sellers. As a rule, a cartel reduces the social welfare[3], thus it is considered an infringement *per se* and does not depend on any interpretation. Cartels are known as the most perverse anti-competitive conduct.

The fight against cartels is a top priority of antitrust authorities. Antitrust policies against collusive agreements are related to penalties setting, cartel investigation and other recent policies that will be discussed later. Despite the importance of the legal discussion, economists are essential to guide policy makers. First, because we are dealing with public expenditure, thus a cost-benefit (or efficiency) analysis is always desirable. Second, econometrics and economic theory are very useful tools to understand and fight collusive practices. An econometric approach can analyze collusive patterns, as price volatility, structural breaks and cartel durations, as well as policy effectiveness. On the other hand, economic theory analyzes the collusion as a game, thus some conclusions may be obtained by game theory modelling.

This thesis consists of three essays on antitrust policies against cartels. Despite independent papers, they are correlated if we consider the understanding of the impact of antitrust policies in Brazil and abroad. Furthermore, they are complementary in the sense of guiding the antitrust enforcement on self-report policies and industries with distinct characteristics.

The first essay focuses on the Brazilian framework. Leniency Programs are recent tools aimed to reduce sanctions against cartel members that report the infringement to the

[2] There is also the *tacit collusion* or *non-cooperative collusion.* It occurs when firms act together but without a formal agreement. An example is when there is a leader in the market that decides to increase the price, then the others decide to follow the decision and also set the prices higher. The result is the same (or almost the same) as a hardcore cartel, but without a formal agreement.

[3] We say as a rule because in some cases the defendants argue in favor of the agreement, for example justifying that without a price-fixing most firms would go bankrupt and only one or two would survive, worsening the situation. This is an unrealistic scenario and not considered in any jurisdiction, as far as we know.

antitrust authority. From a game-theoretical perspective it changes the incentives to deter or destabilize collusive agreements. This policy was first adopted in Brazil in 2000 based on the USA experience.

Despite being considered one of the best tools for fighting cartels, a recent debate about leniency programs is the interplay between the public and private antitrust enforcement. The public stream is the antitrust authority activity, such as investigation and fines settings, while the private enforcement is related to the capacity of agents to require a restitution for the damage suffered using the disclosed information about the infringement. When the cartel member signs the leniency agreement it may be exposed or at least it becomes a target for damage claims, which may discourage the self-report. A current trend is the reduction of damage liability to the one who reports.

The main objective of the first essay is analyzing the best policies for leniency applicants related to the damage liability and disclosure of information in Brazil. We propose a theoretical game based on the Brazilian framework regarding fine setting, recidivism, among other aspects. Assuming that firms compete on prices and have always incentives to collude (the collusive gains are higher or equal the competitive outcome), we contribute to the literature by allowing for the possibility of an endogenous decision on the collusive price, i.e., there exists a set of prices that sustain the collusion instead of the binary choice of collude or not, which is more common in the literature.

The second essay aims at answering a more general question: is the antitrust enforcement against cartels more effective when the products are more homogeneous or differentiated? The literature has been trying to understand the relation between cartel stability and the horizontal product differentiation, since this is an important source of industry differentiation. We contribute to the literature by including the antitrust enforcement in this context.

The theoretical model assumptions are similar to the first essay, but now we focus on the impact of antitrust enforcement on distinct values of the parameter that measures the degree of product differentiation. As the economy is composed by a large number of distinct industries, it is important to understand how they are differently impacted by antitrust policies, thus this type of analysis is essential.

The third essay is an empirical evaluation of the Brazilian Leniency Program. As the empirical literature focuses on USA and EU, it is important to know how these policies work in emerging countries that have particular characteristics regarding the economic environment and antitrust laws, which is the case of Brazil. We test the

Brazilian Leniency Program effectiveness relying on theoretical predictions on the hazard of dissolution of cartels. The hypothesis is that an effective antitrust policy that increases the rate of cartel detection raises the hazard of dissolution of cartels in the long-run, which is consistent to the policy destabilizing capacities.

We rely on survival analysis and hazard functions to estimate the empirical model. A relevant point in our article in comparison to the literature is that we consider the possibility of cartel ending naturally or by antitrust intervention, thus there is more than one cause of cartel dissolution. As the main interest is the policy impact on the natural dissolution, we estimate a "competing risk" model that focus on one cause of ending considering the hazard of the other.

We consider these essays as interconnected parts of a whole thesis. While the first two essays focus on the incentives generated by the antitrust enforcement, the last one evaluates the Leniency Program adopted in Brazil. Through this thesis, we intend to contribute to the literature by understanding how the incentives to collude are changed as antitrust policies are implemented in Brazil and abroad.

LENIENCY AND DAMAGE LIABILITY IN BRAZIL: THE EFFECTS ON COLLUSIVE BEHAVIOR

Abstract: A recent debate about leniency policies is the interplay between public and private competition enforcement. The lack of a well-established set of rules regarding damage claims may be harming the effectiveness of the Brazilian Leniency Program, either by discouraging the wrongdoers from applying for leniency in already formed cartels or by not being threatening enough to deter the cartel formation. The paper objective is to analyze the best policy for leniency applicants related to damage liability in Brazil. We develop a model based on the Brazilian framework and conclude: the optimal policy is providing immunity to the leniency applicant; the immunity is also optimal when there's risk of betrayal, in case of *ex-post* leniency and when there is no bankruptcy, otherwise the liability should be the necessary to avoid the bankruptcy.
Keywords: collusion, leniency, damage claims, damage liability, infinitely repeated game,
JEL code: L13, L41, D43, C73

1. Introduction

The fight against cartels is a major concern of antitrust authorities. Collusive agreements are considered an illegal activity since they reduce the efficiency and often result in increased prices, which is wrongful to the consumers. As informed by OECD (2002), cartels are universally recognized as the most harmful of all types of anticompetitive conducts[4].

In the 90s a new tool for fighting cartels was released by antitrust authorities in developed countries, which Spagnolo (2008) denoted as "*the leniency revolution*". According to the author, leniency policies reduce sanctions against colluding firms that report information on their cartel to the antitrust authority and cooperate with it along the prosecution phase to help convict their former partners. Thus, buyer's complaints, audits

[4] In this paper, we consider a cartel/collusion/collusive agreement as a synonym for an explicit agreement, in which the coordination is evident. The definition of tacit collusion as an illegal activity is not a consensus among antitrust authorities.

and dawn raids have been replaced by well-designed leniency policies and self-reporting mechanisms. Harrington (2008) informs that a well-designed leniency program was first adopted by the United States (USA) in 1993, although some antitrust policies related to amnesty can be observed since 1978. In 1996, the European Commission introduced its own leniency program in the European Union (EU) with some differences in comparison to the USA[5]. Recently, a great number of countries have adopted leniency programs, generally based on USA and EU policies.

In Brazil, the Brazilian System of Competition Policy, led by the Administrative Council for Economic Defense (CADE), began a public fight against cartels in the mid-2000s, releasing booklets aiming at explaining people about their adverse effects and how to denounce collusions, improving mechanisms to prosecute cartels and highlighting the

importance of the Brazilian Leniency Program adopted in 2000. Martinez (2015) informs that the Brazilian Leniency Program was inspired by the USA antitrust policies. A winner-takes-all approach is observed, therefore only the first one to confess can be granted. Companies and individuals can apply for leniency, meaning that a corporation can avoid government fines, while individuals escape fines and prison sentences.

A recent debate about leniency policies discusses the interplay between public and private competition law enforcement. As noted by Spagnolo and Marvão (2016), damage claims may reduce the attractiveness of leniency application for cartel participants if their cooperation with the antitrust authority increases the chance that the victims will bring a successful lawsuit. This conflict requires an intense debate about how antitrust authorities should act regarding damage liability, disclosure of information to victims and the enforcement for encourage lawsuits.

There is no consensus among countries yet. According to Cauffman (2011), in USA the Antitrust Criminal Penalty Enhancement and Reform Act of 2004 limits the civil liability for leniency applicants to single damages attributable to the applicant's own sales, meanwhile the other cartelists are required to cover the additional damages. Without leniency firms are liable for treble damages and are also jointly and severally liable for the entire cartel damage. On top of that, plaintiffs are able to request any relevant information they deem necessary from every wrongdoer, including the leniency applicant. In EU, Buccirossi, Marvão e Spagnolo (2015) highlight that a recent EU Directive states: "*an immunity recipient is jointly and severally liable to: a) its direct or indirect*

[5] See Spagnolo (2008) for a comparison between USA and EU leniency policies.

purchasers or providers; b) to other injured parties only where full compensation cannot be obtained from the other undertakings that were involved in the same infringement of competition law.[6] In addition, *"national courts cannot at any time order a party or a third party to disclose any of the following categories of evidence (a) leniency statement; and (b) settlement submissions"*[7]. Cauffman (2011) cites the Hungary case as an interesting one: a leniency applicant that has been granted immunity from fines may refuse to reimburse the damages as long as the claim can be collected from other undertakings being held liable for the same infringement, i.e., the cartel victims are only able to enforce their claims against the leniency applicant to the extent that it cannot obtain compensation from other cartelists.

As in other countries, the debate in Brazil is recent and not over. According to Martinez (2015), cartel members in Brazil are jointly and severally liable for the illegal activity, with no exception to the leniency applicant. The Brazilian Constitution of 1988 states the disclosure of administrative processes as a rule, however other laws and the CADE internal regiment limit the access of some information, either to protect the investigation or due companies requests to protect market information. The lack of a well-established set of rules regarding damage claims may be harming the effectiveness of the Brazilian Leniency Program, either by discouraging wrongdoers from applying for leniency in already formed cartels or by not being threatening enough to deter the cartel formation. The fight against collusive agreements is a priority for Brazilian antitrust enforcement, therefore it is important to understand the consequences of self-reporting policies to increase the Brazilian Leniency Program effectiveness, already considered one of the best tools for fighting cartels.[8]

The main objective of this paper is to analyze the best policies for leniency applicants related to the damage liability and disclosure of information in Brazil. Instead

[6] The full EU Directive is presented in European Commission (2014) and this quote represents the Article 11, paragraph 4.

[7] Article 6, paragraph 6 of EU Directive.

[8] In Brazil there is also the cartel settlement mechanism, where the member can admit the guilty and pay reduced fines. It could be faced as a leniency mechanism for more than one offender, however we consider the leniency program and cartel settlement as two distinct policies. The first one is more related to the cartel deterrence/destabilization and to incentive the report of an unknown agreement, while the second is more related to the reduction of costs and time of investigation. The interplay between them is out of scope of this paper and we leave this point as a suggestion for future works.

of considering a binary choice of collude or not depending on the incentives (as most papers in this literature), we allow for the possibility of an endogenous decision on the collusive price. The idea is to develop a theoretical framework as close as possible from Brazilian situation regarding competition policies, antitrust authority enforcement and the market itself. Thereby, we can achieve some important conclusions for policy recommendations.

2. Literature review

This paper is related to two important subjects in competition policy. The first one is the interplay between the public and private enforcement of law. Despite being complementary, if not designed cautiously one may be harmful to the other. Important contributions in this field from an economic and theoretical viewpoint include McAffee *et al.* (2008) and Bourjarde *et al.* (2009). More specific to our case, according to Cauffman (2011) two important actions may interfere in this interplay: the law can prevent disclosure of leniency applications; the law can decrease the risk or the amount of damages to be paid by leniency applicants. In practice, it represents no disclosure of information about the leniency agreement until the case is judged and partial liability/immunity of damages to the recipient.

The other important topic is the impact of leniency policies on collusive agreements from a theoretical perspective. Harrington (2008) differentiates two main effects: deterrence (preventing aspect) and desistance. Leniency programs can deter cartel formation either by making it unprofitable or making collusion unstable. On the other hand, leniency programs can cause collusion to desist by expanding the set of future states for which the cartel collapses. Since the seminal paper of Motta and Polo (2003) this is a vast literature that includes Brisset and Thomas (2004), Spagnolo (2005), Aubert *et al.* (2006) Harrington (2008), Lefouili and Roux (2012), Chen and Rey (2013), among others. For Brazil, Moreira and Penaloza (2004) and Vasconcelos and Ramos (2007) has analyzed the Brazilian Leniency Program from a theoretical approach based on game theory. Other studies for Brazil are related to Law, legal aspects and jurisdiction.

Finally, two papers are closer to this one. Buccirossi, Marvão and Spagnolo (2015) is related to the two topics above, i.e., they analyze theoretically the interplay between leniency policies and damage claims. They conclude that private enforcement can improve the level of deterrence if the leniency applicant liability from damages is

very low (immunity ideally), jointly with full disclosure of information to victims. In this sense, their proposal of immunity for the applicant is more effective than the current policy in US, EU and Hungary. The other paper is Houba, Motchenkova and Wen (2015). Inspired by Harrington (2005) and Harrington and Chen (2006), they analyze the impact of a leniency program on the collusive price, thus the decision of collude or not is not binary. Instead, there is a set of prices that sustains the cartel. They conclude that the *ex-ante* leniency is not effective in decreasing the maximal collusive price, while for *ex-post* leniency it is optimal to grant full immunity for the first one to report.

3. The model

3.1. The general framework

The model is an infinitely repeated game, in which firms observe their expected values in each period to make their decisions. An industry consists of two symmetric firms competing *à la* Bertrand *ad infinitum* in a context of any degree of heterogeneity among products (except for completely homogeneous goods[9]). We are interested in the Subgame Perfect Equilibrium (SPE hereafter), the profile of actions that induces Nash equilibrium in every subgame. However, it is well known that repeated games allow for the possibility of multiple SPE, including collusive and non-collusive ones. We analyze the most common and realistic one: the stationary SPE of collude and respect the collusive agreement in every period. Some papers like Motta and Polo (2003), Spagnolo (2005) and Houba, Motchenkova and Wen (2015) also consider the SPE in which firms "exploit" the leniency (since it reduces the costs of misbehavior) by colluding and reporting systematically. However, this is an unrealistic situation and not considered here.

The firm's profit is a function of the price set at the beginning of each period. A competitive duopoly results in both firms setting the Bertrand-Nash price, hereafter p^N, which generates the profit $\pi^N(p^N)$ (π^N from now on). As in Houba, Motchenkova and Wen (2012) and Houba, Motchenkova and Wen (2015), without loss of generality we normalize $\pi^N = 0$, therefore the other profits are net values when compared to the default case of competition. The collusive profit for each firm is $\pi^C(p)$, such that $p \in (p^N, p^M]$

[9] The appendix contains a general example to support our model that works for any degree of differentiation, except for perfect homogeneity.

is the price fixed by the cartel and p^M is the monopoly price. Assuming $\pi^C(p)$ continuous and strictly increasing in $p \in (p^N, p^M]$, firms will always choose the maximal p as possible when colluding (given a set of prices that sustain the cartel and compensates all the risks, they will set the higher one), we call it as "collusive price". Besides competing and colluding, firms can also agree to collude and then deviate, i. e., agree to set the "collusive price" $p > p^N$, but instead of that set a lower price that maximize its profit given the "collusive price" of the other firm. The profit obtained by unilateral deviation is denoted by $\pi^D(p)$[10], continuous and strictly increasing in $p \in (p^N, p^M]$. In the appendix we provide an example of these profits and the respective assumptions. Lastly, we assume the same exogenous discount factor $\delta \in (0,1)$ for both firms.

The Antitrust Authority (AA) acts in two ways: independent investigation and leniency mechanism. Concerning the independent investigation, both firms are detected and prosecuted with probability α when they have done and respected the collusive agreement, such that $\alpha \in (0, \bar{\alpha}]$ due a given budget constraint. Once detected, each firm pays a fine $f\pi^C(p)$ in the same period, with $f \in (0, \bar{f}]$. The Brazilian's Law 12,529/2011 establishes the following criteria related to corporate fines: fine of 1% up to 20% of the company gross revenue in the last year preceding the establishment of the administrative procedure, concerning the business activity branch in which the offense occurred, which will never be lower than the advantage obtained when it is possible to calculate. Considering the profit as a proxy for the revenue, it is plausible to set the fine as a proportion of the total profit obtained in the beginning of each period[11].

With respect to the leniency mechanism, the Brazilian Leniency Program guarantees immunity from fines to the first eligible firm that applies for leniency, just like in USA[12]. Therefore, after an unilateral deviation it is not possible for the betrayed firm to obtain benefits from another leniency agreement. The immunity (total amnesty) may

[10] Note that $\pi^D(p)$ is the profit when the "collusive price" established previously is p, and not the price when deviating.

[11] In Houba, Motchenkova and Wen (2015), both α and f are non-decreasing functions of p. They assume that the higher the price charged by the cartel more distrusted is the AA about the crime. In the same way, the degree of the infringement is a criterion for the penalty statement, thus higher collusive prices induce higher fines. We consider these parameters as exogenous for three reasons: simplicity of the model, the focus is the damage liability and the results are not modified in either.

[12] This approach is considered also in Motta and Polo (1999) and Chen and Harrington (2007), despite most papers allow amnesty for more than one applicant (which represents the European Union case).

be obtained only when the AA is unaware of the collusive activity (*ex-ante* leniency). When the AA knows about the cartel but does not have enough proof to start a prosecution, a leniency applicant can obtain only partial amnesty (from one-third up to two-thirds of the fine as stated by the Brazilian Law 12,529/2011). This is known as *ex-post* leniency and will be considered later as a model extension.

Next, we define the private lawsuit enforcement, i.e., the capacity of agents to sue the cartel for damages. The plaintiffs are allowed to sue the cartel as a whole, then each firm is liable for their own damage when there is no leniency (different liabilities are proposed later)[13]. We take an approach similar to Buccirossi, Marvão and Spagnolo (2015). When the cartel is detected and prosecuted by independent investigation each firm pays a total amount of damages of $\beta d^{NL}\pi^{C}(p)$ in the same period, in which β is a parameter representing the AA enforcement for damage claims (mainly disclosure of evidence to plaintiffs), such that $\beta \in (0, \bar{\beta}]$ and $\bar{\beta}$ is the maximal value given a budget constraint, while d^{NL} represents the civil justice activity, i.e., it is the proportion of the maximum damage request ($\beta\pi^{C}(p)$) set by the court when the firm is not a leniency applicant. Initially, when there is unilateral deviation and reporting the leniency applicant is liable for $\beta d^{L}\pi^{D}(p)$ (different liability rules are proposed later), in which d^{L} is the proportion of the maximum damage request ($\beta\pi^{D}(p)$) set by the court when the firm is in fact the leniency applicant. Note that β is an *ex-ante* policy and invariable with respect to being or not the leniency applicant, while the terms d^{NL} and d^{L} are responsible for distinguish the damage liability of the leniency applicant and the betrayed firm. We assume $d^{L} \leq d^{NL}$, such that when $d^{L} = d^{NL}$ there is no AA policy of distinct liability, when $0 < d^{L} < d^{NL}$ there is a partial liability (the recipient receives a partial amnesty instead of immunity) and when $d^{L} = 0$ there is immunity for the leniency applicant.

As in Buccirossi, Marvão and Spagnolo (2015), we assume it is optimal to apply for leniency (report) when deviating. One possible interpretation for this assumption is that the expected damage liability when reporting ($\beta d^{L}\pi^{D}(p)$) is always lower than the probability of getting caught and be required to pay the fine plus the collusive damage

[13] In theory, it is possible to claim the whole damage from one firm, since each wrongdoer is jointly and severally liable for damages caused by their illegal antitrust activity, i.e., each cartel member may be held liable for the entire cartel-related damage, as highlighted by Martinez (2015). Nevertheless, Martinez (2015) gives an example of a damage claim against a leniency applicant of a cartel in Sao Paulo/Brazil where the judge required the government to amend the claim to also include the other cartel members.

when deviating[14]. Another explanation is the following: α is the probability of detection and prosecution when both collude and respect the collusive agreement, but a deviation may destabilize the market and generate more suspicion, increasing α up to higher levels. In this framework, the probability of being caught may be very high, which induces the leniency application.

Lastly, firms are only liable for fines and damages regarding the current period activity, therefore they are not guilty for past infringements.

3.2. Optimal damage liability

Each firm has two actions to take: collude/respect the collusion (hereafter "collude") and collude/deviate/report ("report" from now on). We consider the grim-trigger strategy, i.e., firms will keep colluding as long as no one "report". If any "report" the cartel dissolves and firms compete *à la* Bertrand forever. The same occurs when a cartel is detected and punished by the AA, it will never be formed again, resulting in competition from thereon. It seems appropriate because no cartel was discovered and punished twice in Brazil, even repeat offenders were members of different cartels[15].

In each period the timing of the game is the following:

1) Firms agree on the "collusive price" $p \in (p^N, p^M]$;

2) Each one decides to follow the agreement or not and realizes the profits. In other words, they choose between "collude" and "report";

3) When both "collude" the AA detects and prosecutes the cartel with probability α. If so, the AA sets the amount of fine and then the court sets the amount of damage for each firm (proportional to the collusive profit), the game ends for that period and firms compete from now on; if not, the game ends for that period and the same game is played

[14] Motta and Polo (2003) and Houba, Motchenkova and Wen (2015) consider the deviating firm immune to antitrust penalties, and in fact some papers like Spagnolo (2005) and Chen and Rey (2013) also argue that this is theoretically optimal, since firms would be more encouraged to deviate when the cost of deviating is lower. However, the Brazilian's Law 12,529/2011 states that an antitrust infringement is any violation of economic order, regardless of fault, which achieved or not the objective. Thus, the intention itself is enough to induce guiltiness.

[15]Motta and Polo (2003) and Houba, Motchenkova and Wen (2015) consider the possibility of a new collusive agreements even after punishment, which is unrealistic in our case.

next period. In case of unilateral "report", the deviating firm receives the benefits of leniency (immunity from fines) and initially pays the amount of damages proportional to the profit from deviation (different liability rules are proposed later), the game ends for that period and firms compete forever[16].

The expected value of "collude" is:

$$V^C(p) = \pi^C(p) - \alpha[f\pi^C(p) + \beta d^{NL}\pi^C(p)] + \delta\left\{\alpha\frac{\pi^N}{1-\delta} + [1 - \alpha]V^C(p)\right\} \quad (1)$$

In which the first part is the profit of colluding, the second part is the total amount of fines and damages when the cartel is detected and the third part is what occurs in the future: firms compete forever or maintain the same expected value. After some manipulation and considering $\pi^N = 0$ we have:

$$V^C(p) = \pi^C(p)\frac{[1-\alpha f-\alpha\beta d^{NL}]}{[1-\delta+\delta\alpha]} \quad (2)$$

We assume $1 - \alpha f - \alpha\beta d^{NL} \geq 0$, therefore $V^C(p) \geq 0$ and there are always incentives for cartelization. Also, $V^C(p)$ is strictly increasing in $p \in (p^N, p^M]$ due the fact that $\pi^C(p)$ is strictly increasing in $p \in (p^N, p^M]$. Next, we define the expected value of unilateral "report":

$$V^R(p) = \pi^D(p) - 0 - \beta d^L\pi^D(p) + \delta\frac{\pi^N}{1-\delta} \quad (3)$$

The first part is the profit of unilateral deviation, the second part is the immunity from fines guaranteed by the Brazilian Leniency Program when the AA is unaware about the infringement, the third part is the amount of damages to be paid and the last one is the competitive outcome forever. Again, we assume $1 - \beta d^L \geq 0$, therefore $V^D(p) \geq 0$ and strictly increasing in $p \in (p^N, p^M]$ due $\pi^D(p)$ strictly increasing in $p \in (p^N, p^M]$.

[16] Note that we are analyzing the cartel behavior regarding one specific stationary SPE: collude and respect the collusive agreement. The pay-off when both "report" plays no role here (it will be important later in the model extension "bankruptcy").

The incentive compatibility constraint (ICC) is given by $V^C(p) \geq V^R(p)$. This condition states "collude" as a SPE and sets the maximal "collusive price" ($V^C(p) = V^R(p)$)[17]. Considering $\pi^N = 0$, the ICC be expressed as:

$$\frac{\pi^C(p)}{\pi^D(p)} \geq \frac{[1-\delta+\delta\alpha][1-\beta d^L]}{[1-\alpha f-\alpha\beta d^{NL}]} \tag{4}$$

As in Houba, Motchenkova and Wen (2015), the term $\pi^C(p)/\pi^D(p)$ can be interpreted as the relative gains of the collusive profit in comparison to the gains of unilateral deviation. We assume that an increase in p increases the profit of unilateral deviation at a higher rate than the collusive profit, thus the fraction is strictly decreasing in p (an example is provided in the appendix). The right-hand side of (4) is denoted by ω and the following proposition formalizes the first result:

Proposition 1*: Assuming $\pi^C(p)/\pi^D(p)$ strictly decreasing in $p \in (p^N, p^M]$, either the price is p^N or there exists a maximal "collusive price" $p \in (p^N, p^M]$ satisfying $V^C(p) \geq V^R(p)$.*

Proof: Consider that $\pi^C(p)/\pi^D(p)$ is left-bounded by $\pi^C(p^N)/\pi^D(p^N) = 1$, while ω is exogenous. We have three possible cases:

1) If $\pi^C(p^N)/\pi^D(p^N) < \omega$ the price is p^N and $V^C(p) < V^R(p) \ \forall \ p \in (p^N, p^M]$ (total deterrence);

2) If $\pi^C(p^M)/\pi^D(p^M) \leq \omega < \pi^C(p^N)/\pi^D(p^N)$ there is an interior solution $p^I \in (p^N, p^M]$ such that $V^C(p^I) = V^R(p^I)$ constraining the "collusive price" (partial deterrence);

3) If $\pi^C(p)/\pi^D(p) > \omega \ \forall \ p \in (p^N, p^M]$ the "collusive price" is p^M and $V^C(p) > V^R(p) \forall \ p \in (p^N, p^M]$ (no deterrence). □

The first case of the proof above represents a combination of a small δ, a big α and high values of f and βd^{NL}. The third one is the opposite: firms are patient (high δ),

[17] This is the same as if we consider a firm's maximization problem of p in the form of: $Max\, p \in (p^N, p^M]$ *subject to* (4).

the independent investigation is small (low α) and f and βd^{NL} are also small. We are more interested in the second case (intermediate cases), i.e., when the combination of parameters that compose ω provides an interior solution $p^I \in (p^N, p^M]$. This is the most realistic framework: firms have incentives to collude and set $p^I > p^N$, but they are not able to act freely and the ICC binds the endogenous decision such that $p^I \leq p^M$. The Figure 1 below illustrates this scenario:

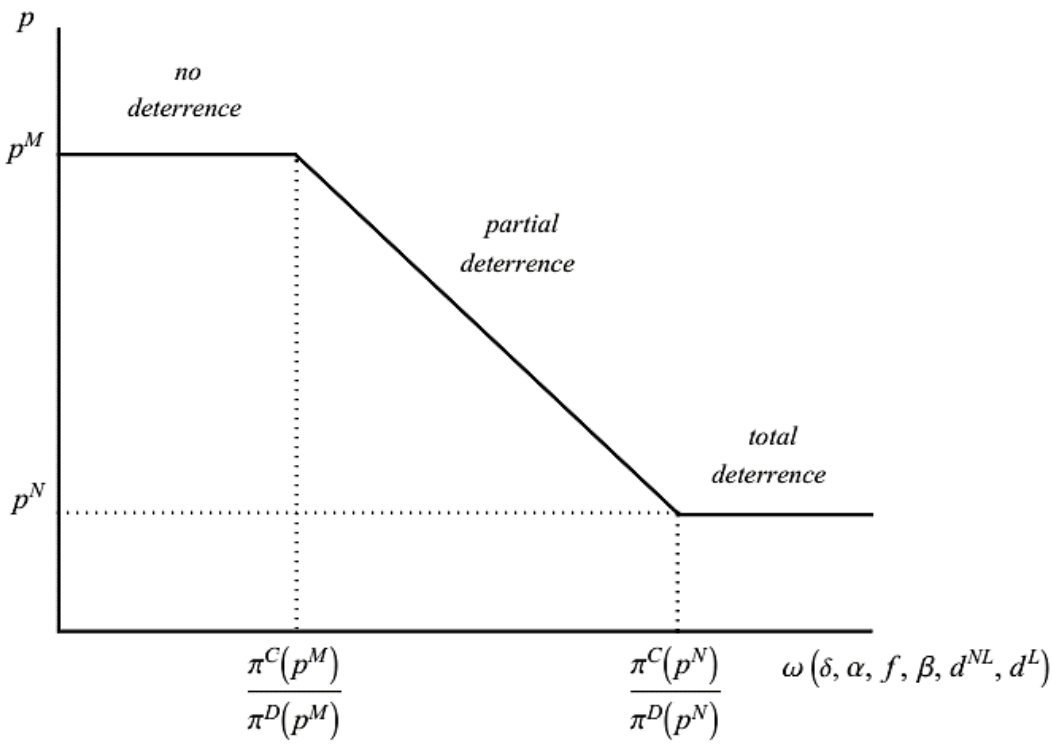


Figure 1. The three levels of deterrence

Now we analyze the AA activity. Assuming the cartel will form anyway when $p = p^I \in (p^N, p^M]$, the objective is to decrease the "collusive price" as much as possible. The closer is p^I from p^N the lower is the profit and the deadweight loss (and higher is the consumer surplus). From a simple comparative statics analysis, it is clear from (4) that an increase in α strengthens the ICC (as shown in the appendix), thus it is optimal to increase the AA independent investigation as much as possible. With respect to the AA enforcement for damage claims the situation is the following: ω is either decreasing or increasing in β depending on the parameters (as shown in the appendix). This is because when the leniency applicant is liable for damages we have an adverse effect: while an increase in β reduces $V^C(p)$ at a rate $(\alpha\beta d^{NL})/(1-\delta+\delta\alpha)$, it also decreases $V^R(p)$ at

a rate βd^L, thus the consequences might be more in the sense of discourage the report than reduce the gains of collusion. The following proposition states the optimal antitrust policy regarding the damage liability:

Proposition 2*: From the AA perspective of decreasing the "collusive price", it is optimal to set* $d^L = 0$ *. After that, the impact of* β *in reducing the "collusive price" is higher.*

Proof: The ICC is strengthened when $d^L = 0$. It shifts ω upward in (4) up to ω^* and decreases the "collusive price" to p^*, such that $p^* < p^I$. Any other policy that reduces the damage liability for the leniency applicant but does not provide immunity is sub-optimal since the "collusive price" obtained lies between p^* and p^I. At the same time, the comparative statics in the appendix shows that a decrease in d^L turns the impact of β on ω more positive/less negative. The maximal positive impact of β on ω is obtained when $d^L = 0$. It occurs because with any other policy that reduces the damage liability for the leniency applicant, but does not provide immunity, the adverse effect of discouraging the report remains. □

Lastly, the AA policies of setting $d^L = 0$ and increasing β maintains "collude" as a SPE for all $p \in (p^N, p^M]$. Consider β exogenous and define the "collusive price" after the immunity by p^* . Furthermore, denote the value of unilateral "report" after the immunity as $V^{R*}(p) = \pi^D(p)$. In the absent of the immunity the "collusive price" is set when $V^C(p^I) = V^R(p^I)$, but since $V^{R*}(p) > V^R(p) \ \forall \ p \in (p^N, p^M]$ we have $V^C(p^I) < V^{R*}(p^I)$, thus this policy strengthens the ICC up to $V^C(p^*) = V^{R*}(p^*)$, "collude" remains a SPE and since $p^* < p^I$ the amount of damage is lower and the consumer surplus is higher than before[18]. The same occurs with an increase in β after $d^L = 0$: it will reduce $V^C(p)$, which generates a new ICC equilibrium and a new "collusive price" strictly lower than before.

4. Further extensions

4.1. The risk of betrayal affecting the "collusive price"

[18] If $p^* = p^N$ this policy results in completely cartel deterrence.

We are considering the sustainability of the stationary SPE in which firms collude and respect the collusive agreement in every period ("collude"). Before, the ICC was set by comparing the expected value of "collude" to the expected value of unilateral "report", which determines the "collusive price" and turns "collude" into a SPE. Nevertheless, as pointed out by Spagnolo (2005) and Buccirossi, Marvão and Spagnolo (2015), the risk of betrayal is an important channel of deterrence, thus it is important to consider this effect in the analysis. It means that no firm is absolutely sure about the other's decision. By consequence, the ICC is no longer obtained by comparing the value of "collude" to the value of unilateral "report", since there is no certainty about unilateral "report" (the other one can also "report"). Instead of this, firms assign a probability for each action of the other member and compare the expected pay-off when playing "collude" to the expected pay-off when playing "report".

Following Spagnolo (2005) and Buccirossi, Marvão and Spagnolo (2015), to consider the fear of betrayal we apply an important concept developed by Harsanyi and Selten (1988): the equilibrium selection criterion of *risk dominance*. Harsanyi and Selten (1988) argue that in games with multiple equilibria it is possible to use an equilibrium selection criterion to define which one is most likely. They propose two criteria: the pay-off dominance and the risk dominance. In the first one the idea is that an equilibrium that provides higher pay-offs for all players dominates the others, while in the second one the dominating equilibrium is the less risky for all players. Spagnolo (2005) and Buccirossi, Marvão and Spagnolo (2015) provides support for these concepts with experimental examples.

As informed by Buccirossi, Marvão and Spagnolo (2015), the *risk dominance* points at the less risky equilibrium, i.e., when the consequences of the opponent not playing the equilibrium strategy are less negative. In our case, we are interested in the unique collusive SPE, when both "collude" (remember that both "report" is not a SPE, despite being a Nash equilibrium in an one-shot game). Thus, for our purposes, this concept is important because it changes the riskiness of "collude", as shown from now on. The game that generates "collude" as a SPE is represented in Table 1:

Table 1. The payoff matrix of the infinitely repeated game

	C	R
C	$V^C(p), V^C(p)$	$V^{OR}(p), V^R(p)$
R	$V^R(p), V^{OR}(p)$	$V^{BR}(p), V^{BR}(p)$

In which $V^C(p)$ and $V^R(p)$ were already defined, while $V^{OR}(p)$ and $V^{BR}(p)$ are the expected value when the other "report" and when both "report", respectively. We state the following:

$$V^{OR}(p) = \pi^{OD}(p) - f\pi^{OD}(p) - \beta d^{NL}\pi^{OD}(p) + \delta\frac{\pi^N}{1-\delta} \quad (5)$$

$$V^{BR}(p) = \pi^{BD}(p) - \frac{1}{2}[0 + \beta d^{L}\pi^{BD}(p)] - \frac{1}{2}[f\pi^{BD}(p) + \beta d^{NL}\pi^{BD}(p)] + \delta\frac{\pi^N}{1-\delta} \quad (6)$$

In (5) the firm is cheated, obtains the lowest possible profit $\pi^{OD}(p)$ (other deviates) and pays the fine and damage with sure (we consider d^{NL} because the firm is not the leniency applicant). In (6) the term $\pi^{BD}(p)$ is the profit obtained when both deviate, and since only the first one to report is able for leniency we consider it a random event. When both "report" each one has a probability of ½ of being immune from fines (first brackets) and a probability of ½ of paying the whole fine (second brackets). We state $\pi^{BD}(p)$ strictly increasing in $p \in [p^N, p^M]$ and $\pi^{OD}(p)$ strictly increasing up to a point and then strictly decreasing in $p \in [p^N, p^M]$ (an example is provided in the appendix).

We follow the procedure developed by Harsanyi and Selten (1988)[19]. The matrix in Table 1 is transformed into an equivalent one that represents the net gains of each equilibrium. This matrix can be expressed as in Table 2 below:

Table 2. The equivalent matrix of the infinitely repeated game:

[19] Check Harsanyi and Selten (1988) and Buccirossi, Marvão and Spagnolo (2015) for further details.

	C	R
C	$V^C(p) - V^R(p), V^C(p) - V^R(p)$	0,0
R	0,0	$V^{BR}(p) - V^{OR}(p), V^{BR}(p) - V^{OR}(p)$

Note that an increase in $V^R(\cdot)$ reduces the gains of "collude", making it less attractive. At the same time, a decrease in $V^{OR}(\cdot)$ makes "report" more attractive for both. It is possible to measure this relative risk by the *riskiness index* (γ), defined by:

$$\gamma = [V^{BR}(p) - V^{OR}(p)]^2 - [V^C(p) - V^R(p)]^2 \tag{7}$$

When $\gamma < 0$ we say that "report" is risk dominated by "collude", while $\gamma > 0$ means the opposite and $\gamma = 0$ represents the equivalence. Comparing to the Proposition 1, if $\gamma < 0 \ \forall \ p \in (p^N, p^M]$ there is no deterrence, while if $\gamma > 0 \ \forall \ p \in (p^N, p^M]$ there is total deterrence. As we are interested in the "collude" SPE only the case when $\gamma \leq 0$ matters, i.e., an interior solution given by the equality in the new ICC is the interest. Considering $\gamma = 0$ the new ICC can be expressed by:

$$V^C(p) - V^R(p) \geq V^{BR}(p) - V^{OR}(p) \tag{8}$$

Replacing (2), (3), (5) and (6) in (8), considering $\pi^N = 0$ and after some manipulation we reach the new ICC that ensures "collude" a SPE and sets the "collusive price":

$$\frac{\pi^C(p)}{\pi^D(p)} \geq \frac{[1-\delta+\delta\alpha]}{1-\alpha f-\alpha\beta d^{NL}} \left\{ [1 - \beta d^L] + \frac{\pi^{BD}(p)}{\pi^D(p)} \left[1 - \frac{f}{2} - \frac{\beta(d^L + d^{NL})}{2} \right] - \frac{\pi^{OD}(p)}{\pi^D(p)} [1 - f - \beta d^{NL}] \right\} \tag{9}$$

We denote the right-hand side of (9) as $\omega_{risk}(p)$. Maintaining the same assumptions of *Proposition 1*, this new ICC is more restrictive than (4) when:

$$\frac{\pi^{BD}(p)}{\pi^D(p)} \left[1 - \frac{f}{2} - \frac{\beta(d^L + d^{NL})}{2} \right] > \frac{\pi^{OD}(p)}{\pi^D(p)} \left[1 - f - \beta d^{NL} \right] \forall \, p \in [p^N, p^M] \tag{10}$$

This is true because $\pi^{BD}(p) > \pi^{OD}(p)\ \forall\ p \in [p^N, p^M]$ (the example in the appendix gives support to that) and $[1 - f/2 - \beta(d^L + d^{NL})/2] > [1 - f - \beta d^{NL}]$. Therefore, the "collusive price" obtained in (9) is strictly smaller than p^I in (4), which would be expected because the risk of betrayal reduces the gains of collusion and restrict any collusive equilibrium. We denote this new "collusive price" as p_{risk}.

Now we focus on the immunity from damage claims. Note that it generates $V^{R*}(p) = \pi^D(p)$ as defined previously, but it also changes $V^{OR}(p)$ and $V^{BR}(p)$ because the betrayed firm is liable for the entire cartel damage (his own and the other's). We denote these new values as:

$$V^{OR*}(p) = \pi^{OD}(p) - f\pi^{OD}(p) - \beta d^{NL}\pi^{OD}(p) - \beta d^{NL}\pi^{D}(p) + \delta\frac{\pi^N}{1-\delta} \quad (11)$$

$$V^{BR*}(p) = \pi^{BD}(p) - \frac{1}{2}[f\pi^{BD}(p) + \beta d^{NL}\pi^{BD}(p) + \beta d^{NL}\pi^{BD}(p)] + \delta\frac{\pi^N}{1-\delta} \quad (12)$$

The ICC after the immunity is $V^C(p) - V^{R*}(p) \geq V^{BR*}(p) - V^{OR*}(p)$, which gives us the following:

$$\frac{\pi^C(p)}{\pi^D(p)} \geq \frac{[1-\delta+\delta\alpha]}{1-\alpha f-\alpha\beta d^{NL}}\left\{[1+\beta d^{NL}] + \frac{\pi^{BD}(p)}{\pi^D(p)}\left[1-\frac{f}{2}-\beta d^{NL}\right] - \frac{\pi^{OD}(p)}{\pi^D(p)}[1-f-\beta d^{NL}]\right\} \quad (13)$$

Note that the immunity strengthens the ICC at a higher degree than without considering the risk of betrayal. The right-hand side of (4) was already denoted by ω, now consider that the immunity shifts ω upwards up to $\omega^* = [1-\delta+\delta\alpha]/[1-\alpha f-\alpha\beta d^{NL}]$ in (4). At the same time, the immunity shifts $\omega_{risk}(p)$ in (9) up to $\omega^*_{risk}(p)$ (the right-hand side of (13)). We can state the following:

$$\omega^* - \omega = \beta d^L\frac{(1-\delta+\delta\alpha)}{1-\alpha f-\alpha\beta d^{NL}} \quad (14)$$

$$\omega^*_{risk}(p) - \omega_{risk}(p) = \left\{\beta d^{NL}\left[1-\frac{\pi^{BD}(p)}{2\pi^D(p)}\right] + \beta d^L\left[1+\frac{\pi^{BD}(p)}{2\pi^D(p)}\right]\right\}\frac{(1-\delta+\delta\alpha)}{1-\alpha f-\alpha\beta d^{NL}} \quad (15)$$

Since $0 < \pi^{BD}(p)/2\pi^{D}(p) < 1 \; \forall \; p \in [p^N, p^M]$ due to $\pi^{BD}(p) < \pi^{D}(p) \forall \; p \in [p^N, p^M]$, the right-hand side in (15) is strictly higher than the right-hand side in (14). It occurs because besides increasing $V^{R}(p)$ up to $V^{R*}(p)$ by pulling out $\beta d^{L}\pi^{D}(p)$, the immunity also decreases $V^{OR}(p)$ up to $V^{OR*}(p)$ by adding $\beta d^{NL}\pi^{D}(p)$ to the penalty. Denoting this new price as p^{*}_{risk}, we see that $p^{*}_{risk} < p^{*}$ because $\omega^{*}_{risk}(p) > \omega^{*} \; \forall \; p \in (p^N, p^M]$, thus it is possible to conclude that the immunity from damage claims for the leniency applicant is even more effective in reducing the "collusive price" when the risk of betrayal is considered.

4.2.Ex-post leniency

Until now, we have been assuming that firms decide between "collude" and "report" before any investigation, i.e., the AA is unaware about the cartel activity and starts to investigate/prosecute only after their decision. It is possible to call this case as *ex-ante* leniency, but in many cases firms choose their actions when the AA is already investigating the cartel, which can possibly change the collusive SPE. This situation is denoted by Houba, Motchenkova and Wen (2015) as *ex-post* leniency.

As mentioned in the introduction, an important difference here is that when the AA knows about the cartel activity the leniency applicant can only obtain partial amnesty, from one-third up to two-thirds of the estimated fine (stated by the Brazilian's Law 12,529/2011). We denote the amount of fine the applicant is liable as $\vartheta\pi^{D}(p)$, such that $\vartheta \in (0, f)$, i.e., the applicant is never granted full immunity ($\vartheta > 0$), but he always receives partial amnesty ($\vartheta < f$).

In the main model, we stated α as the probability of independent investigation and prosecution by the AA. It is possible to think of it as two distinct activities: the AA may launch an investigation on the market and may detect the cartel with probability $\rho \in (0, \bar{\rho})$; then, after the cartel detection the AA may successfully prosecute it with a probability $\mu \in (0, \bar{\mu})$. As both are probabilities (restricted between zero and one) we have $\rho > \alpha$ and $\mu > \alpha$. Before, we were considering $\alpha = \rho\mu$ and both launched at the same time, but now the timing of the game is the following:

1) Firms agree on the "collusive price" $p \in (p^N, p^M]$ simultaneously;

2) The AA launches the investigation on the market and detects the cartel with probability ρ;

3) Each firm chooses between "collude" and "report" and realizes the profits.

4) When both "collude":

i) If detected, the AA successfully prosecutes the cartel with probability μ, each firm pays the fines and damages, the game ends for that period and they compete from now on.

ii) If detected but not successfully prosecuted no one is penalized, the game ends for that period and both play the same game in the next period.

iii) If not detected, each one earns the collusive profit and both play the same game in the next period.

With respect to the unilateral "report":

i) Like in Motta and Polo (2003), we assume it occurs only when the cartel is detected. In this case the applicant pays the reduced fine and the amount of damage (different liability rules are proposed later), the game ends for that period and firms compete forever.

ii) If the cartel is not detected the deviating firm earns the profit of unilateral deviation, the game ends for that period and both compete from now on.

Now we define the values of "collude" and "report"[20] under *ex-post leniency*, respectively (already considering $\pi^N = 0$):

$$V^C_{ex-post}(p) = \rho\{\pi^C(p) - \mu[f\pi^C(p) + \beta d^{NL}\pi^C(p)] + [1 - \mu]\delta V^C_{ex-post}(p)\} + (1-\rho)[\pi^C(p) + \delta V^C_{ex-post}(p)] \quad (16)$$

$$V^R_{ex-post}(p) = \rho[\pi^D(p) - \vartheta\pi^D(p) - \beta d^L\pi^D(p)] + (1-\rho)\pi^D(p) \quad (17)$$

[20] As in the main model, it is always optimal to report when deviating,

We assume $V^{C}_{ex-post}(p) \geq 0 \ \in \forall\, p \in (p^{N}, p^{M}]$ and $V^{R}_{ex-post}(p) \geq 0 \ \in \forall\, p \in (p^{N}, p^{M}]$. The new "collusive price" is set by $V^{C}_{ex-post}(p) \geq V^{R}_{ex-post}(p)$, therefore:

$$\frac{\pi^{C}(p)}{\pi^{D}(p)} \geq \frac{[1-\delta+\delta\mu]\left[1-\rho\vartheta-\rho\beta d^{L}\right]}{[1-\rho\mu f-\rho\mu\beta d^{NL}]} \tag{18}$$

Denote the right-hand side of (18) as $\omega_{ex-post}$ and the new "collusive price" as $p_{ex-post}$. While an increase in μ enhances $\omega_{ex-post}$, thus it is optimal to increase the capacity of prosecution as much as possible, the same problem of increasing β without immunity in the main model occurs with ρ now: an increase in ρ reduces $V^{C}_{ex-post}(p)$ at an amount of $(\rho\mu f - \rho\mu\beta d^{NL})/(1-\delta+\delta\alpha)$, but it also decreases $V^{R}_{ex-post}(p)$ at an amount of $(\rho\vartheta - \rho\beta d^{L})$, thus besides the impact of reducing the gain from collusion, it also discourages the reporting. The fact is that setting $d^{L}=0$ is the optimal policy in this framework as well: it shifts $\omega_{ex-post}$ upward up to $\omega^{*}_{ex-post}$ and removes the adverse effect of ρ in $V^{R}_{ex-post}(p)$ regarding the damages. As a consequence, the "collusive price" is decreased from $p_{ex-post}$ to $p^{*}_{ex-post}$.

Finally, what about the relation between the "collusive prices" in *ex-ante* and *ex-post* frameworks? Due the Brazilian Leniency Program rules for *ex-post* leniency it is not possible to reach an overall conclusion. The fact of existing ϑ (the leniency applicant receives partial amnesty and not full immunity) means that the adverse effect of ρ with respect to ϑ remains after $d^{L}=0$. Since $\omega^{*}=[1-\delta+\delta\alpha]/[1-\alpha f-\alpha\beta d^{NL}]$, $\omega^{*}_{ex-post}=[1-\delta+\delta\mu][1-\rho\vartheta]/[1-\rho\mu f-\rho\mu\beta d^{NL}]$, $\alpha=\rho\mu$ and $\mu>\alpha$, we have $\omega^{*}_{ex-post}>\omega^{*}$ when $[1-\delta+\delta\mu]/[1-\delta+\delta\alpha]>1/(1-\rho\vartheta)$, so $p^{*}_{ex-post}<p^{*}$ when this inequality holds. In this situation, it is better for the AA to launch the investigation and try to detect the cartel before the decision to "collude" or "report", otherwise it is better to wait and set $\alpha=\rho\mu$ togheter. This problem would vanish if the AA follows the suggestion of Houba, Motchenkova and Wen (2015): the most effective *ex-post* leniency policy for lowering the "collusive price" of silent cartels should grant full immunity to the applicant[21]. Setting $\vartheta=0$ would result in $\omega^{*}_{ex-post}>\omega^{*}$ and

[21] There is a worry regarding this suggestion. Consider that an investigation is ongoing, but the suspects are innocents. Full immunity could induce type II errors, i.e., an innocent could apply for leniency if the lawsuit costs are larger than the expected penalty with leniency (zero in this case). This is a theoretical worry, in

$p^*_{ex-post} < p^*$ in all circumstances, and in this case the anticipated investigation would always be worth it.

4.3.Bankruptcy

In the previous sections we assumed that when one firm applies for leniency (and receives immunity from damages) the other one can afford for the total amount of damages claimed. Depending on the fine set by the AA, plus the damage payment, perhaps the betrayed firm is unable to pay this entire amount and goes bankrupt, resulting in a market concentration for the future periods.

We assume the bankruptcy only occurs when one firm chooses "report", i.e., if the cartel is discovered by independent investigation they both can afford the damages. Thereafter, the expected value of "collude" is the same as (1). Now we define the new expected value for the one who "report". After the bankruptcy, the leniency applicant becomes a monopolist from now on for an unknown period, for simplicity we say forever. Thereby, the firm will be able to set p^M indiscriminately and the expected value of "report" becomes:

$$V_B^R(p) = \pi^D(p) + \delta \frac{\pi^M(p^M)}{1-\delta} \tag{19}$$

In which $\pi^M(p^M)$ is the monopolist profit at the monopoly price. Note that $V_B^R(p) > V^R(p) \; \forall \; p \in (p^N, p^M]$, thus the ICC is strengthened with the bankruptcy and, by consequence, the "collusive price" p_B is lower than p^I.

Apparently, the immunity for the recipient is even more effective in a bankruptcy scenario. However, there are two points we need to address. The first one is that if the AA commits to the immunity and to a high enforcement of damage claims the betrayed firm may go bankrupt and maybe some plaintiffs will not be able to receive the refund (once it cannot be charged from the recipient). We consider that the proven claim is a right set by the civil justice, thus someone needs to pay for it, even more in jurisdictions where each firm is jointly and severally liable for the entire cartel damage (as Brazil).

practice it is hard to believe that an innocent would assume the guilty since it could damage the company image, the CEOs career, among other aspects

Secondly, it is hard to believe that the antitrust authority will be directly responsible for bankruptcy and market concentration[22] (except for authorized mergers). Since β is an *ex-ante* policy, if the betrayed firm informs and proves that $d^L = 0$ will lead to bankruptcy the AA will be directly responsible for this. Thereby, we determine a new expected value of "report":

$$V_B^{R*}(p) = \pi^D(p) - \beta d_B^L \pi^D(p) + \delta \frac{\pi^N}{1-\delta} \tag{20}$$

The term d_B^L represents the AA policy regarding the damage liability for the leniency applicant with the risk of bankruptcy. From this perspective, the optimal d_B^L should be zero in the case of no bankruptcy or the minimum necessary for no bankruptcy otherwise (and π^N henceforward because the monopoly will not occur). In other words, to guarantee the refund for those who claimed, maybe it is necessary to charge a certain amount from the leniency applicant. It may weak the ICC up to a "collusive price" $p_B^* > p_B$, but is necessary to guarantee the right of refund and the integrity of firms.

This point was considered in Buccirossi, Marvão and Spagnolo (2015), but from another perspective. They assume that when the betrayed firm goes bankrupt another one will replace it immediately. The immunity from damage claims increases the "minimum discount factor" that sustains the cartel, as a consequence a group of cartels that would form in the absence of this policy will not form anymore. In case of bankruptcy there is a trade-off: if the AA commits to the immunity some plaintiffs will not be refunded, and if the difference is charged from the leniency applicant the ICC is weakened. The authors affirm that the immunity is optimal even in this case, since a higher "minimum discount factor" prevents the cartel formation, thus the damage of potential cartels is avoided. If we consider the damage of potential cartels and of actual cartels at the same weight, it is better to avoid the total amount of damages by preventing the cartel formation than leaving some plaintiffs without refund.

We argue the opposite in this extension. Considering the plaintiff's right to restitution and the market concentration, the optimal policy in Brazil should be: immunity for the leniency applicant and maximum enforcement of damages as a rule; the recipient

[22] The fines defined by the law have a preventive and punitive purpose. The Brazilian's Antitrust Law nº 12,529/2011 defines the economic situation of the offender as a criterium for the fine, precisely to not being responsible for bankruptcy and market concentration.

will be liable only if the amount of damages cannot be charged from the others due bankruptcy[23]. As informed by Cauffman (2011) and Buccirossi, Marvão and Spagnolo (2015), these policies recommendations are close to the Hungary framework, in which the leniency applicant is only required to pay damages if the plaintiff cannot obtain compensation from other cartelists.

5. Conclusions

The interplay between private and public antitrust enforcement is an important issue nowadays. Regarding the leniency policies there are two main points to discuss, the damage liability for the leniency applicant and the AA enforcement for damage claims. The situation in Brazil is not different and these topics are calling the attention of economists, lawyers, and people from law and economics in general.

The main objective of this paper was to analyze the best policies for leniency applicants related to the damage liability and disclosure of evidence in Brazil. We considered the cartel as a living organism, able to change the "collusive price" and to adapt itself according to distinct policies and situations. In the main model we concluded that it is optimal to grant immunity to the leniency applicant, as well as increase as much as possible the AA enforcement for damage claims. The three extensions confirmed the following: the immunity is even more effective when there is risk of betrayal; the immunity is the best policy in the case of *ex-post* leniency, but due the Brazilian Leniency Program rules we cannot conclude that the "collusive price" in an *ex-post* leniency framework is always lower than in *ex-ante* leniency scenario; the immunity is the optimal policy when there is no bankruptcy, otherwise the applicant liability should be the minimum necessary to avoid the bankruptcy and to guarantee the refund to plaintiffs.

Despite that the model has been developed based on the Brazilian structure of antitrust law, the results may be helpful to other jurisdictions as well. The private enforcement of damage claims is a powerful channel of deterrence, but in a context of leniency it may discourage the applicant if there is a fear of being sued for damages. The

[23] One would think that the AA could increase the enforcement of damage claims (increase β), but in the case of bankruptcy they could reduce this enforcement to guarantee the immunity for the leniency applicant (maybe denying proofs and information). Nevertheless, we assume β as an *ex-ante* and general policy, therefore it cannot change according to the circumstances.

leniency applicant should to be protected from that, and maybe the partial liability as in US is not the best policy. Our approach is closer to the one adopted in Hungary.

In the model, we assumed that profits, fines and damages do not accumulate over time. It means that in each period there is a new independent value for these terms, so the firm is liable only for the damage done in the current period. It is possible to consider the cartel behavior in a dynamic context of accumulation. If the cartel lasts for ten years, firms will be liable for the damage done in this entire period, and possibly this fact modifies the cartel pricing over time. We leave this suggestion for future works.

6. Appendix

6.1. An example of $\boldsymbol{\pi^C(p)}$ and $\boldsymbol{\pi^D(p)}$ strictly increasing in $\boldsymbol{p \in (p^N, p^M]}$

Suppose one demand function for each firm: $D_1(p_1) = a - bp_1 + cp_2$ and $D_2(p_2) = a - bp_2 + cp_1$, $p_1, p_2 \in [p^N, p^M]$, with $D_1(p_1), D_2(p_2) \geq 0$ and $p_1, p_2 \geq 0$. The parameter a is the maximum demand, b is the own-price effect and c is the cross-price effect. The higher is c higher is the similarity between products, thus $c = 0$ indicates completely differentiated products and at the limit $c = b$ indicates homogeneous products[24]. We assume the goods are substitutes, which implies c positive, and $b > c$, so that when colluding they will face a negative demand function. We also assume marginal costs equal to zero, therefore when colluding they are going to set the same price (there is no difference among market share, scale gains, etc.).

When both compete *a la* Bertrand the profit for each firm is ${\pi^N}_1 = (a - bp_1 + cp_2)p_1$ and ${\pi^N}_2 = (a - bp_2 + cp_1)p_2$, which results in $p^N = a/(2b - c)$ by Bertrand equilibrium. After that, denote the profit function after the collusive agreement[25] by $\pi^M(p) = 2(a - bp + cp)p$, $p \in (p^N, p^M]$. The first order condition states $p = p^M = a/2(b - c)$. Finally, the profit of each firm after the cartel is denoted by:

[24] Strictly speaking, as considered in Chen and Rey (2013) and Buccirossi, Marvão and Spagnolo (2015), in a context of homogeneity an unilateral deviation provides twice the collusive profit (the deviating firm will set a price marginally lower than the collusive one and will sell for the entire market), thus the collusive price set does not matter (the ratio between the profit of collude and deviate is always half). This assumption works well for them, but since our analysis is focused on the cartel behavior on price we opted for a different approach.

[25] Like if they were acting as a monopolist.

$$\pi^C(p) = (a - bp + cp)p \tag{21}$$

And the first and second derivatives:

$$\frac{\partial \pi^C(p)}{\partial p} = a - 2p(b - c) \tag{22}$$

$$\frac{\partial^2 \pi^C(p)}{\partial p^2} = -2(b - c) \tag{23}$$

Since $b > c$ the first order condition in (22) represents a maximum point in (21), therefore $\partial \pi^C(p)/\partial p > 0 \; \forall \; p \in (p^N, p^M]$ and by consequence $\pi^C(p)$ is strictly increasing in $p \in (p^N, p^M]$.

Next, we assume the deviating firm takes the collusive price as given and then maximize its own profits. The price of deviation is a function of the "collusive price", we denote it as $p^D(p)$. The profit function when the firm deviates from the agreement is:

$$\pi^D(p) = (a - bp^D(p) + cp)p^D(p) \tag{24}$$

And the first order condition regarding $p^D(p)$ states the reaction function $p^D(p) = (a + cp)/2b$. Replacing the reaction function in (24) and taking the first derivative we have:

$$\frac{\partial \pi^D(p)}{\partial p} = \frac{2ac + 2c^2 p}{4b} \tag{25}$$

From (25) it is clear that $\partial \pi^D(p)/\partial p > 0 \; \forall \; p \in (p^N, p^M]$, thus $\pi^D(p)$ is strictly increasing in $p \in (p^N, p^M]$.

6.2. An example of $\boldsymbol{\pi^{BD}(p)}$ strictly increasing in $\boldsymbol{p \in (p^N, p^M]}$ and $\boldsymbol{\pi^{OD}(p)}$ strictly increasing up to a point and then strictly decreasing in $\boldsymbol{p \in (p^N, p^M]}$

As a sequence of the previous example, the profit $\pi^{BD}(p)$ occurs when both set the deviating price simultaneously, consequently:

$$\pi^{BD}(p) = [a - bp^{D}(p) + cp^{D}(p)]p^{D}(p) \tag{26}$$

Replacing the reaction function $p^{D}(p) = (a + cp)/2b$ in (26) and calculating the first derivative we have:

$$\frac{\partial \pi^{BD}(p)}{\partial p} = \frac{2ac^2 + 2c^3p - 2bc^2p}{4b^2} \tag{27}$$

After some algebraic manipulation we see that $\partial \pi^{BD}(p)/\partial p > 0 \; \forall \; p \in (p^N, p^M]$ as long as $a/(b - c) > p$, which is the case for all $p \in (p^N, p^M]$ (remember $p^N = a/(2b - c)$ and $p^M = a/2(b - c)$). Hence, $\pi^{BD}(p)$ is strictly increasing in $p \in (p^N, p^M]$.

The profit $\pi^{OD}(p)$ occurs when the firm sets the "collusive price" p while the other cheats and set $p^{D}(p)$. It can be represented by:

$$\pi^{OD}(p) = [a - bp + cp^{D}(p)]p \tag{28}$$

After replacing $p^{D}(p) = a + cp/2b$ in (28) and obtaining the first derivative we have:

$$\frac{\partial \pi^{OD}(p)}{\partial p} = \frac{2ba - 4b^2p + ac + 2c^2p}{2b} \tag{29}$$

Note that this expression is strictly negative when $p > p^{IP} = [a(2b + c)]/[4b^2 - 2c^2]$, however this value represents an inflection point $p^N < p^{IP} < p^M$ (p^{IP} of "inflection point"). When $p^N \leq p < p^{IP}$, we have $\partial \pi^{OD}(p)/\partial p > 0$ and $\pi^{OD}(p)$ strictly increasing in $p \in (p^N, p^{IP})$, while when $p^{IP} \leq p < p^M$, we have $\partial \pi^{OD}(p)/\partial p < 0$ and $\pi^{OD}(p)$ is strictly decreasing in $p \in (p^{IP}, p^M]$.

6.3. An example of $\boldsymbol{\pi^{C}(p)/\pi^{D}(p)}$ strictly decreasing in $\boldsymbol{p \in (p^N, p^M]}$:

Replacing the reaction function $p^D(p) = (a + cp)/2b$ in (24), we can express the ratio by the following:

$$\frac{\pi^C(p)}{\pi^D(p)} = \frac{(a-bp+cp)p}{[a-b\left(\frac{a+cp}{2b}\right)+cp]\left(\frac{a+cp}{2b}\right)} \tag{30}$$

Denote $\pi^C(p)/\pi^D(p) = \varphi(p)$. Taking the first derivative and after some algebraic manipulation:

$$\frac{\partial\varphi(p)}{\partial p} = \frac{\frac{a}{4b}[a^2+c^2p^2+2acp-2abp-2bcp^2]}{\left[\frac{a^2+2acp+c^2p^2}{4b}\right]^2} \tag{31}$$

To guarantee $\varphi(p)$ decreasing in p, we need $\partial\varphi(p)/\partial p < 0 \;\forall\; p \in (p^N, p^M]$. Note that the denominator is strictly increasing and strictly positive in $p \in (p^N, p^M]$, while the numerator is strictly decreasing in $p \in (p^N, p^M]$ due to:

$$\frac{\partial\frac{a}{4b}[a^2+c^2p^2+2acp-2abp-2bcp^2]}{\partial p} = -\frac{a}{4b}[2cp(2b-c) + 2a(b-c)] < 0 \;\forall\; p \in (p^N, p^M] \tag{32}$$

Consider also that $\pi^C(p^N) = \pi^D(p^N)$, thus $\varphi(p^N) = \pi^C(p^N)/\pi^D(p^N) = 1$ and $\partial\varphi(p^N)/\partial p^N = 0$. Therefore, $\partial\varphi(p)/\partial p$ starts with zero and is strictly negative when $p \in (p^N, p^M]$, thereby $\varphi(p)$ is strictly decreasing in $p \in (p^N, p^M]$.

6.4. Comparative statics on ω:

$$\frac{\partial\omega}{\partial\alpha} = \frac{\delta(1-\beta d^L)\left(1-\alpha f-\alpha\beta d^{NL}\right)+\left(f+\beta d^{NL}\right)(1-\delta+\delta\alpha)(1-\beta d^L)}{(1-\alpha f-\alpha\beta d^{NL})^2} \tag{33}$$

Since all terms inside the parentheses are positive the derivative is positive.

$$\frac{\partial\omega}{\partial\beta} = \frac{-(1-\delta+\delta\alpha)\left[d^L\left(1-\alpha f-\alpha\beta d^{NL}\right)-\alpha d^{NL}(1-\beta d^L)\right]}{(1-\alpha f-\alpha\beta d^{NL})^2} \tag{34}$$

We see that the derivative is zero when $d^L(1-\alpha f) = \alpha d^{NL}$, is negative when $d^L(1-\alpha f) > \alpha d^{NL}$ and positive when $d^L(1-\alpha f) < \alpha d^{NL}$.

7. References

AUBERT, C.; REY, P.; KOVACIC, W. E. The Impact of Leniency and Whistle Blowing Programs on Cartels. *International Journal of Industrial Organization*. V. 24, Nº 6 , p. 1241-1266. 2006.

BOURJADE, S.; REY, P.; SEABRIGHT, P. Private antitrust enforcement in the presence of pre-trial bargaining. *The Journal of Industrial Economics*, n. 57 (3), p. 372–409. 2009.

BRISSET, K.; THOMAS, L. Leniency Program: A New Tool in Competition Policy to Deter Cartel Activity in Procurement Auctions. *European Journal of Law and Economics*. V. 17, Nº 1, p. 5-19. 2004.

BUCCIROSSI, P.; MARVÃO, C.; SPAGNOLO, G. Leniency and Damages. 2015. *CEPR Discussion Paper No. DP10682*. Available in https://ssrn.com/abstract=2624637. Accessed in: April 7, 2017.

CAUFFMAN, C. The Interrelationship between Leniency and Damages Actions. *Competition Law Review*. P. 181-220. 2011.

CHEN, J.; HARRINGTON, J. E. The Impact of the Corporate Leniency Program on Cartel Formation and the Cartel Price Path. In Vivek Ghosal, Johan Stennek (ed.)*: "The Political Economy of Antitrust"*, Emerald Group Publishing Limited. pp.59 – 80. 2007.

CHEN, Z.; REY, P. On the design of leniency programs. *Journal of Law and Economics*, Vol. 56, No. 4, p. 917-957. 2013

EUROPEAN COMISSION. 2014. Directive of the European Parliament and of the Council on certain rules governing actions for damages under national law for infringements of the competition law provisions of the member states and of the European

Union. Available in: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0104. Accessed in: April 7, 2017.

HARRINGTON, J. E. "Optimal Cartel Pricing in the Presence of an Antitrust Authority." *International Economic Review*, v. 46, p. 145–170. 2005.

HARRINGTON, J. E. Optimal Corporate Leniency Programs. *The Journal of Industrial Economics*, V. 56, Nº 2, p. 215–246. 2008.

HARRINGTON, J. E.; CHEN, J. Cartel Pricing Dynamics with Cost Variability and Endogenous Buyer Detection. *The International Journal of Industrial Organization*, v.24, nº6, p. 1185–1212. 2006.

HARSANYI, J.; SELTEN, R. A general theory of equilibrium selection in games. The MIT Press, Vol. 1. 1988. 378p

HOUBA, H.; MOTCHENKOVA, E.; Wen, Q. Competitive prices as optimal cartel prices. *Economics Letters*, v. 114, n. 1, p. 39-42. 2012.

HOUBA, H.; MOTCHENKOVA, E.; Wen, Q. The Effects of Leniency on Cartel Pricing. *The BE Journal of Theoretical Economics*, *15*(2), 351-389. 2015.

LEFOUILI, Y.; ROUX, C. Leniency programs for multimarket firms: The effect of Amnesty Plus on cartel formation. *International Journal of Industrial Organization*, V. 30, Nº 6, p. 624-660. 2012.

MARTINEZ, A. P. Challenges Ahead of Leniency Programmes: The Brazilian Experience. *Journal of European Law and Practice*. V. 6, Nº 4, p. 260-267. 2015.

MCAFEE, R. P.; MIALON, H. M.; MIALON, S. H. Private v. public antitrust enforcement: a strategic analysis. *Journal of Public Economics*, n. 92, p. 1863 – 1875. 2008.

MOREIRA, E. A. S.; PENALOZA, R. Programas de Leniência, Corrupção e o Papel da Corregedoria da Autoridade Antitruste. In: XXXII Encontro Nacional de Economia, 2004, João Pessoa, Paraíba. *Anais do XXXII ENCONTRO NACIONAL DE ECONOMIA*, Anpec, 2004. *P. 1-20.*

MOTTA, M.; POLO, M. Leniency Programs and Cartel Prosecution. *International Journal of Industrial Organization*. V. 21, Nº 3, p. 347-379. 2003.

OECD - Organization for Economic Co-operation and Development. (2002). Fighting Hard Core Cartels: Harm, Effective Sanctions and Leniency Programmes. Competition Law and Policy Report. Available in: http://www.oecd.org/competition/cartels/1841891.pdf. Accessed in: April 5, 2017.

SPAGNOLO, G. Divide et Impera: Optimal leniency programmes, *CEPR Discussion Papers nº 4840*. 2005.

SPAGNOLO, G. Leniency and Whistleblowers in Antitrust. In: BUCCIROSSI, P (ed). *Handbook of Antitrust Economics*, Cambridge, MIT Press. 2008. p. 259-304.

SPAGNOLO, G.; MARVÃO, C. 2016. Cartels and Leniency: Taking Stock of What We Learnt. Available in: https://ssrn.com/abstract=2850498. Accessed in: April 20, 2017.

VASCONCELOS, S. P.; RAMOS, S. F. Análise da Efetividade do Programa de Leniência Brasileiro no Combate aos Cartéis. *Working Paper 008/2007*. Juiz de Fora. 2007.

ANTITRUST ENFORCEMENT AND HORIZONTAL PRODUCT DIFFERENTIATION

Abstract: An important issue for antitrust researchers and policy makers is how the antitrust enforcement can deter and/or destabilize cartels in different industries. The horizontal product differentiation is a relevant source of industry differentiation. Some papers studied the interplay between the degree of product differentiation and the cartel stability, we give a step forward in this literature by answering the following question: is the antitrust enforcement against cartels more effective when products are more homogeneous or differentiated? Based on a standard Bertrand duopoly, in which the cartel profit depends on the "collusive price", we conclude that the antitrust enforcement is more effective in constraining the "collusive price" when products are more homogeneous, although the total deterrence of all cartels occurs at the same point. This type of information is essential for guiding the public enforcement of competition law.
Keywords: antitrust enforcement; cartel; product differentiation; collusive price
JEL codes: L13, L41, D43, C73

1. Introduction

Fighting cartels is a top priority for antitrust authorities. The perverse effects of collusive agreements are well known: they tend to reduce the allocative efficiency by generating supernormal profits and deadweight loss. They also tend to decrease the consumer surplus and the incentives to foster competitive advantages as innovations, cost reduction and so on. Therefore, explicit cartels are illegal and represent the most harmful anticompetitive conduct.

According to Spagnolo (2008), a cartel is a type of organized crime, in which three important characteristics stand out: it requires the cooperation among several agents, thus problems of free riding and opportunism arise; in general, it is a continuous activity, even in procurements it is common for the members to act in several occasions; each member is informed about the other's misconduct. Considering these aspects, a collusive agreement is naturally risky and unstable.

An important issue nowadays is how the public enforcement of competition law can deter and/or destabilize cartels. The antitrust enforcement related to collusive agreements aims at reducing the incentives of collusion, either by decreasing the expected

profits (higher fines, higher probability of detection, among other policies that increase the costs of collusion) or by increasing the risk of other member reporting the infringement (leniency policies).

As highlighted by Ivaldi et al. (2007), some industry characteristics facilitate the collusion, for instance a low number of competitors and a high degree of entry barriers. Regarding the horizontal product differentiation, the answer is not clear. The impact depends on the type of competition (prices or quantities) and how the model is designed. As informed by Song and Wang (2017), when products are horizontally less differentiated the deviation becomes more profitable, however the punishment is more severe. Another way to look at this issue is from a contract costs viewpoint. When products are homogeneous the contract costs generated by a collusive agreement tend to be lower, as the costs of logistic, labor, inputs and so on then to be similar, as well as the final price. When products are highly differentiated it is harder to reach the collusive agreement terms.

Horizontal product differentiation is not intrinsically good or bad. According to Baker (1997), consumers usually benefit from the availability of a wide variety of product offerings to serve their differing preferences. On the other hand, differentiation can facilitate the exercise of market power because the seller often enjoys a localized monopoly and may be able to charge a higher price than it otherwise could.

Since the 80s many papers have been trying to understand the relation between cartel stability and horizontal product differentiation. One stream analyzes the collusive strategic behavior by Bertrand and/or Cournot competition, such as Deneckere (1983), Rothschild (1992), Albaek and Lambertini (1992) and Song and Wang (2017). A second stream uses spatial models of competition, generally Hotelling and/or Salop models, as Chang (1991) and Ross (1992). As far as we know, no paper considered the antitrust enforcement in this framework[26].

We intend to contribute to this literature by answering the following question: is antitrust enforcement against cartels more effective when products are horizontally more homogeneous or differentiated? Based on a standard Bertrand duopoly in which firms

[26] In Frübing and Polk (2016), the authors analyze the impact of leniency programs on cartel stability in industries with different degrees of product differentiation, nevertheless they use a distinct methodology from the cited papers (and from this one). Based on a numerical Bertrand model, the study concludes that more profitable cartels consisting of producers of closer substitutes tend to be less stable. Thus, leniency programs do in fact threaten more harmful cartels.

agree on prices, we aim to understand the impact of antitrust action on the ability of different cartels to sustain the collusive price. "Effectiveness" in our context means the capacity of constrain the cartel price.

The impact of antitrust enforcement on collusive incentives is a fundamental topic in the literature because it guides the antitrust authority activity. Including horizontal product differentiation in this analysis is essential. For instance, it could indicate if the antitrust authority should focus on discovering and punishing more homogeneous cartels or should aim at cartels with products more differentiated. Since the antitrust enforcement must be carefully designed and well implemented it is essential to understand its consequences.

2. The model

2.1. The main framework

An industry consists of two symmetric firms competing on prices. The model is an infinitely repeated game and we are interested in the Subgame Perfect Equilibrium (SPE) of collude and respect the collusion ("collude" hereafter). Each firm can also collude and unilaterally deviates ("deviate" from here on).

The profit is a function of the price defined at the beginning of the period. A competitive duopoly competition results in both firms setting the Bertrand-Nash price, hereafter p^N, which generates the profit $\pi^N(p^N)$. Without loss of generality, we normalize $\pi^N(p^N) = 0$. The collusive profit for each firm is $\pi^C(p)$, such that $p \in (p^N, p^M]$ is the price fixed by the cartel ("collusive price" hereafter) and p^M is the monopoly price. We assume $\pi^C(p)$ continuous and strictly increasing in $p \in (p^N, p^M]$. The profit obtained by unilateral deviation is denoted by $\pi^D(p)$[27], also continuous and strictly increasing in $p \in (p^N, p^M]$. The exogenous discount factor $\delta \in (0,1)$ is the same for both firms.

The antitrust enforcement consists of independent detection and fines. Both firms are detected and prosecuted with probability α when they choose "collude", such that $\alpha \in (0, \overline{\alpha}\,]$ due to a given budget constraint. Once detected, each one pays a fine $f\pi^C(p)$ in the same period, such that $f \in (0, \overline{f}]$ and $\overline{f} \leq 1$. Following Houba, Motchenkova and

[27] Note that $\pi^D(p)$ is the profit when the "collusive price" combined previously is p, and not the price when deviating.

Wen (2012) there is no punishment for the one who chooses "deviate". Furthermore, firms are only liable for fines regarding the current period.

We consider the grim-trigger strategy, i.e., firms will keep colluding as long as no one chooses "deviate" or the cartel is detected. In any of these events the cartel dissolves and firms compete forever. In each period the timing of the game is the following:

1) Firms agree on the "collusive price" $p \in (p^N, p^M]$;
2) They choose between "collude" and "deviate".
3) When both "collude" the AA detects and prosecutes the cartel with probability α. If so, the AA sets the amount of fine, the game ends for that period and firms compete from now on; if not, the game ends for that period and the same game is played next period. In case of unilateral "deviate" the game ends for that period and firms compete thereafter.

The expected value of "collude" is:

$$V^C(p) = \pi^C(p) - \alpha f \pi^C(p) + \delta\{\alpha \frac{\pi^N(p^N)}{1-\delta} + [1 - \alpha]V^C(p)\} \quad (1)$$

We assume $1 - \alpha f \geq 0$, therefore $V^C(p) \geq 0$ and there are always incentives for collusion. The expected value of unilateral "deviate" is:

$$V^D(p) = \pi^D(p) + \delta \frac{\pi^N(p^N)}{1-\delta} \quad (2)$$

The "incentive compatibility constraint" (ICC) is given by $V^C(p) \geq V^D(p)$. This condition establishes "collude" as a SPE and defines the "collusive price" when the equality holds. The ICC is the following:

$$\frac{\pi^C(p)}{\pi^D(p)} \geq \frac{[1-\delta+\delta\alpha]}{[1-\alpha f]} \quad (3)$$

The left-hand side is denoted by $\varphi(p)$. We interpret it as the relative gains of choose "collude" in comparison to the gains of unilateral deviation. On the other hand, the right-hand side, denoted by ω, is exogenous and depends on the antitrust policies, besides the

discount factor. Note that ω is strictly increasing in α and f. The first proposition is the following:

Proposition 1*: Assume $\varphi(p)$ strictly decreasing in $p \in (p^N, p^M]$. Either the price is p^N or there exists a maximal "collusive price" $p \in (p^N, p^M]$ satisfying $V^C(p) \geq V^D(p)$.*

Proof: The function $\varphi(p)$ is left-bounded by $lim_{p \to p^N} \varphi(p) = 1$. There are three possible cases:

1) If $\varphi(p^N) \leq \omega$, the price is p^N and $V^C(p) < V^D(p)$ (the cartel is totally deterred);

2) If $\varphi(p^M) \leq \omega < \varphi(p^N)$, there is an interior solution $p^I \in (p^N, p^M]$ such that $V^C(p^I) = V^D(p^I)$ constraining the "collusive price" (the cartel is partially deterred);

3) If $\varphi(p^M) > \omega$, the "collusive price" is p^M and $V^C(p) > V^D(p)$ (no deterrence). □

This second case is the most realistic one: firms have incentive to collude and set $p^I > p^N$, but they are not able to act freely and the ICC constrains the endogenous decision, such that $p^I \leq p^M$.. The Figure 1 below represents this scenario[28]:

[28] We expose $\varphi(p)$ as a linear function, just for illustration. We do not deal with the slope and concavity of $\varphi(p)$ since this is not important for results.

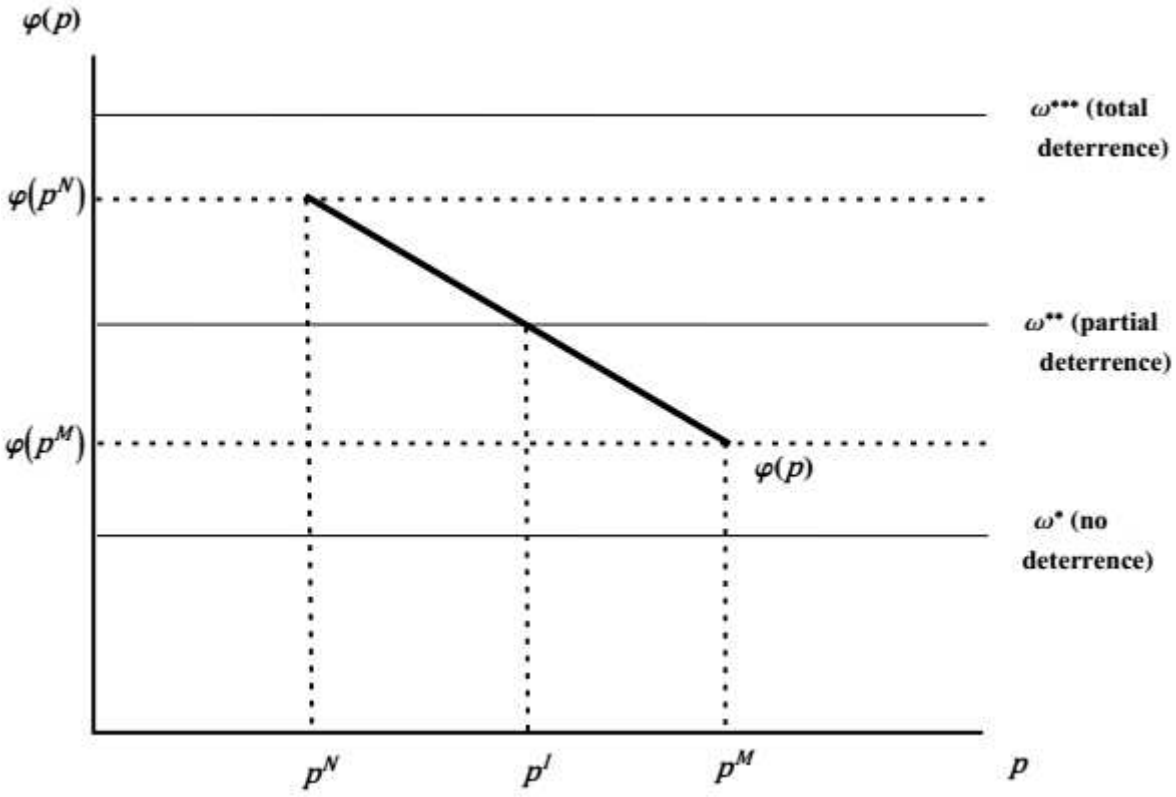


Figure 1. The three levels of deterrence and the "collusive price" setting

2.2.The degree of product differentiation

Now we provide a specific model according to the previous assumptions. Suppose one demand function for each firm: $D_1(p_1) = a - bp_1 + cp_2$ and $D_2(p_2) = a - bp_2 + cp_1$, $p_1, p_2 \in [p^N, p^M]$, with $D_1(p_1), D_2(p_2) \geq 0$ and $p_1, p_2 \geq 0$. The parameter a is the maximum demand, b is the own-price effect and c is the cross-price effect. The higher is c higher is the similarity between products, thus $c = 0$ indicates completely differentiated products, while $c = b$ (at the limit) indicates homogeneous products. Goods are substitutes, which implies $c \geq 0$, and $b > c$, thus when colluding they will face a negative demand function. We also assume marginal costs equal to zero, therefore they set the same price when colluding.

When both compete the profits are ${\pi^N}_1 = (a - bp_1 + cp_2)p_1$ and ${\pi^N}_2 = (a - bp_2 + cp_1)p_2$, which results in $p_1 = p_2 = p^N = \frac{a}{(2b-c)}$ as the Bertrand equilibrium. Denote the joint profit function after the collusive agreement by $\pi^M(p) = 2(a - bp +$

$cp)p$, $p \in (p^N, p^M]$. The first order condition states $p^M = \frac{a}{2(b-c)}$. Finally, the profit for each firm after the cartel is denoted by:

$$\pi^C(p) = (a - bp + cp)p \tag{4}$$

The first and the second derivatives are $\frac{\partial \pi^C(p)}{\partial p} = a - 2p(b - c)$ and $\frac{\partial^2 \pi^C(p)}{\partial p^2} = -2(b - c)$, therefore the first order condition is a maximum point and $\pi^C(p)$ is strictly increasing in $p \in (p^N, p^M]$, as assumed in the previous section.

Next, assume that the deviating firm takes the collusive price as given and then maximize its own profits. The price of deviation is a function of the "collusive price". We denote it as $p^D(p), p \in (p^N, p^M]$. The profit function when the firm unilaterally deviates is:

$$\pi^D(p) = (a - bp^D(p) + cp)p^D(p) \tag{5}$$

The first order condition regarding $p^D(p)$ states $p^D(p) = \frac{(a+cp)}{2b}$. Replacing in (5) and taking the first derivative, we have $\frac{\partial \pi^D(p)}{\partial p} = \frac{(2ac+2c^2p)}{4b}$. Note that $\frac{\partial \pi^D(p)}{\partial p} > 0 \; \forall \; p \in (p^N, p^M]$, thus $\pi^D(p)$ is strictly increasing in $p \in (p^N, p^M]$, as assumed in the previous section.

As before, the fraction $\pi^C(p)/\pi^D(p)$ is denoted as $\varphi(p)$ and expressed by:

$$\varphi(p) = \frac{(a-bp+cp)p}{(a-b(\frac{a+cp}{2b})+cp)(\frac{a+cp}{2b})} \tag{6}$$

The first derivative is:

$$\frac{\partial \varphi(p)}{\partial p} = \frac{\frac{a}{4b}[a^2+c^2p^2+2acp-2abp-2bcp^2]}{[\frac{a^2+2acp+c^2p^2}{4b}]^2} \tag{7}$$

We need $\varphi(p)$ strictly decreasing in $p \in (p^N, p^M]$, as assumed in the main model. The denominator in (7) is positive and strictly increasing in $p \in (p^N, p^M]$, while the numerator (denote it as $\beta(p)$) is strictly decreasing in $p \in (p^N, p^M]$ due to:

$$\frac{\partial \beta(p)}{\partial p} = -\frac{a}{4b}[2cp(2b-c) + 2a(b-c)] < 0 \; \forall \; p \in (p^N, p^M] \tag{8}$$

Note that $\varphi(p^N) = \frac{\pi^C(p^N)}{\pi^D(p^N)} = 1$ and $\frac{\partial \varphi(p^N)}{\partial p^N} = 0$, therefore $\frac{\partial \varphi(p)}{\partial p}$ starts with zero and is strictly decreasing in $p \in (p^N, p^M]$, meaning that it is strictly negative in $p \in (p^N, p^M]$. By consequence, $\varphi(p)$ is strictly decreasing in $p \in (p^N, p^M]$, as defined in the previous section.

Next, we analyze the equilibrium when the degree of product of differentiation changes. It is worth noting that a change in c modifies the functions $\pi^C(\cdot)$, $\pi^D(\cdot)$ and $\varphi(\cdot)$, but it also changes the functions domains. Due this reason, a comparative statics analysis will not be helpful. We rather compare the functions with different levels of c in order to obtain general conclusions. After that, we are able to analyze the impact of antitrust policies.

Suppose two values of c, $\underline{c}$ and $\overline{c}$, such that $\underline{c} < \overline{c}$. The respective functions are $\varphi\left(\underline{c}, \underline{p}\right), \underline{p} \in (\underline{p}^N, \underline{p}^M]$, with $\underline{p}^N = a/(2b - \underline{c})$ and $\underline{p}^M = a/2(b - \underline{c})$, while $\varphi(\overline{c}, \overline{p}), \overline{p} \in (\overline{p}^N, \overline{p}^M]$, with $\overline{p}^N = a/(2b - \overline{c})$ and $\overline{p}^M = a/2(b - \overline{c})$. Both functions start with one and end at the respective monopoly price. Finally, it is clear that $\underline{p}^N < \overline{p}^N$ and $\underline{p}^M < \overline{p}^M$, i.e., the competitive price and the monopoly price are higher when the products are less differentiated.

The following propositions are provided:

Proposition 2: *For all* $\varphi\left(\underline{c}, \underline{p}\right) = \varphi(\overline{c}, \overline{p})$, $\underline{p} \in \left(\underline{p}^N, \underline{p}^M\right]$ *and* $\overline{p} \in (\overline{p}^N, \overline{p}^M]$, *we have* $\overline{p} > \underline{p}$.

Proof: Based on the Figure 2 below, this proposition states that $\varphi(\overline{c}, \overline{p})$ is always on the right of $\varphi\left(\underline{c}, \underline{p}\right)$. Using (6), we see that $\varphi\left(\underline{c}, \underline{p}\right) = \varphi(\overline{c}, \overline{p})$ when:

$$2a^2\underline{p}\overline{p}(\overline{c}-\underline{c})+a\left(\overline{c}^{\,2}\underline{p}\overline{p}^{\,2}-\underline{c}^{\,2}\overline{p}\underline{p}^{\,2}\right)+a^2b\left(\overline{p}^{\,2}-\underline{p}^{\,2}\right)-2ab\left(\overline{c}\,\overline{p}\underline{p}^{\,2}-\underline{c}\,\underline{p}\overline{p}^{\,2}\right)-$$
$$b\left(\overline{c}^{\,2}\underline{p}^{\,2}\overline{p}^{\,2}-\underline{c}^{\,2}\overline{p}^{\,2}\underline{p}^{\,2}\right)-a^3\left(\overline{p}-\underline{p}\right)-a^2\left(\overline{c}\,\overline{p}^{2}-\underline{c}\,\underline{p}^{2}\right)+2a\underline{c}\overline{c}\left(\overline{p}\underline{p}^{2}-\underline{p}\overline{p}^{\,2}\right)+$$
$$\underline{p}^{\,2}\overline{p}^{\,2}\left(\underline{c}\,\overline{c}^{\,2}-\overline{c}\underline{c}^{\,2}\right)=0 \qquad (9)$$

The proof requires (9) only when $\overline{p}>\underline{p}$. We prove by contradiction. Assume $\underline{p}=\overline{p}=\underline{\overline{p}},\ \underline{\overline{p}}\in\left(\overline{p}^{\,N},\underline{p}^{\,M}\right]$, such that the equality is only possible on the domains intersection (when $\left(\underline{p}^{\,N},\underline{p}^{\,M}\right]\cap\left(\overline{p}^{\,N},\overline{p}^{\,M}\right]\neq\{0\}$, otherwise prices are never equal). After some manipulation, we reach the following condition for $\varphi\left(\underline{c},\underline{\overline{p}}\right)=\varphi\left(\overline{c},\underline{\overline{p}}\right)$:

$$\underline{\overline{p}}^{2}\overline{c}\,\underline{c}+a^2-2ab\underline{\overline{p}}+\underline{\overline{p}}\left(\overline{c}+\underline{c}\right)\left(a-b\underline{\overline{p}}\right)=0 \qquad (10)$$

The expression (10) is a contradiction because when $\underline{\overline{p}}=\overline{p}^{\,N}$ the left-hand side (denoted by $\vartheta(\underline{\overline{p}})$) becomes $-b\left(\overline{c}-\underline{c}\right)$, clearly negative. Furthermore, $\vartheta(\underline{\overline{p}})$ is strictly decreasing in $\underline{\overline{p}}$ due:

$$\frac{\partial\vartheta(\underline{\overline{p}})}{\partial\underline{\overline{p}}}=-a\left(2b-\overline{c}-\underline{c}\right)-2\underline{\overline{p}}\,\overline{c}\left(b-\underline{c}\right)-2b\underline{\overline{p}}\,\overline{c}<0\ \forall\ \underline{\overline{p}}\in\left(\overline{p}^{\,N},\underline{p}^{\,M}\right] \qquad (11)$$

Thus, $\vartheta(\underline{\overline{p}})$ starts negative and strictly decreases as $\underline{\overline{p}}$ increases, confirming the contradiction in (10). Since $\underline{p}^{\,N}<\overline{p}^{\,N}$ and given that $\varphi\left(\underline{c},\underline{p}\right)$ and $\varphi(\overline{c},\overline{p})$ never intercept, for all $\varphi\left(\underline{c},\underline{p}\right)=\varphi(\overline{c},\overline{p})$ we have $\overline{p}>\underline{p}$. □

Proposition 3*: Denote* $\varphi\left(\underline{c},\underline{p}^{\,M}\right)=\varphi(\overline{c},p^*)$, $p^*>\underline{p}^{\,M}$. *For a subset* $\bar{\bar{p}}\in(p^*,\overline{p}^{\,M}]$ *we have* $\varphi\left(\underline{c},\underline{p}^{\,M}\right)>\varphi(\overline{c},\bar{\bar{p}})\ \forall\ \bar{\bar{p}}\in(p^*,\overline{p}^{\,M}]$.

Proof: This proposition says that the range of $\varphi(\overline{c},\overline{p})$ is always higher than $\varphi\left(\underline{c},\underline{p}\right)$. In Proposition 2 we stated that $p^*>\underline{p}^{\,M}$ when $\varphi\left(\underline{c},\underline{p}^{\,M}\right)=\varphi(\overline{c},p^*)$. By definition, $\underline{p}^{\,M}<p^*<\overline{p}^{\,M}$, thus there is a domain subset between p^* and $\overline{p}^{\,M}$ (denoted by $\bar{\bar{p}}$) included only

in $\varphi(\overline{c},\overline{p})$. Since $\varphi(\overline{c},\overline{p})$ is strictly decreasing in all $\overline{p} \in (\overline{p}^{N},\overline{p}^{M}]$, it is also strictly decreasing in the subset $\bar{\bar{p}} \in (p^{*},\overline{p}^{M}]$, resulting that the range of $\varphi(\overline{c},\overline{p})$ is higher than $\varphi\left(\underline{c},\underline{p}\right)$. □

Given the relation between $\varphi\left(\underline{c},\underline{p}\right)$ and $\varphi(\overline{c},\overline{p})$ discussed above, as well as ω representing the antitrust enforcement (assuming the same parameters for both industries), the Figure 2 illustrates this framework:

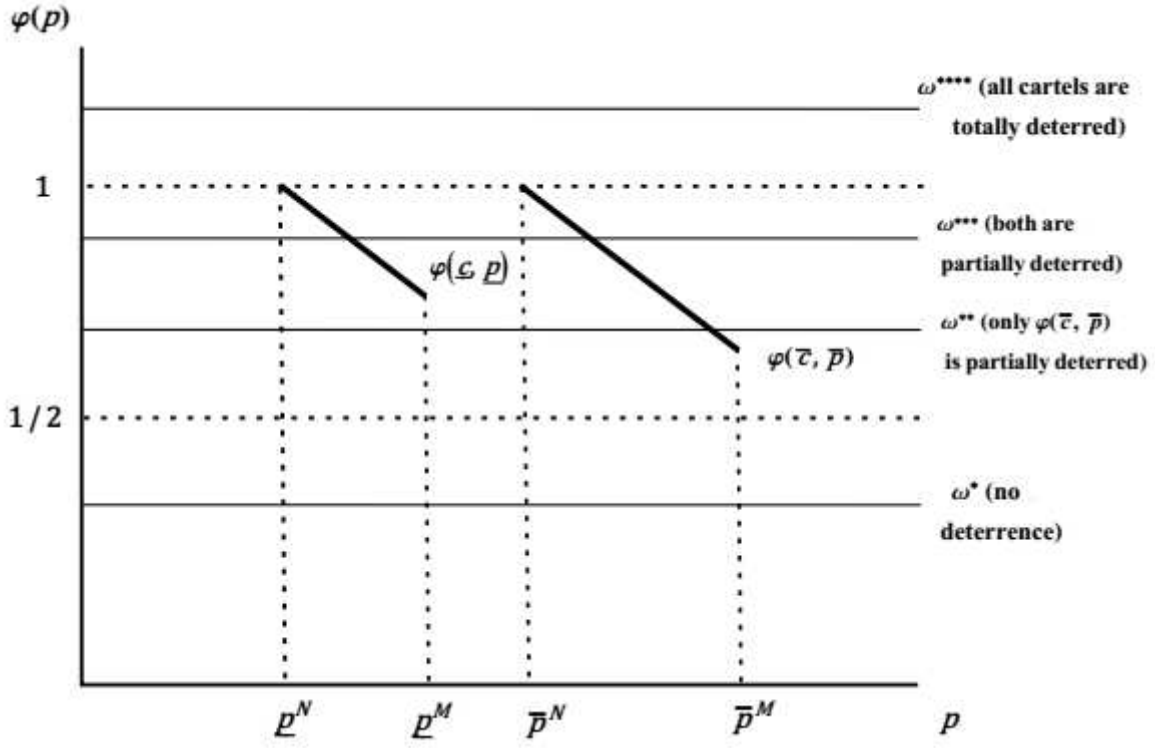


Figure 2. The different values of ω and the cartel deterrence.

Finally, we can analyze the impact of antitrust policies on different industries. Considering that $\varphi(p) \geq \omega$ in (3), suppose a *continuum* of industries, such that $c \in (0, b)$. If $1/2 \geq \omega$ there is no deterrence even in cartels with a high degree of product homogeneity[29]. If we consider $1 > \omega > 1/2$ a low value of ω is binding only in

[29] In theory, $\varphi(p) = ½$ represents the perfect homogeneity ($c = b$). If one firm deviates and sets a price marginally lower it will get the entire demand, obtaining the total monopoly profit (twice the value of collude).

industries with a high degree of homogeneity (high c), and if ω increases new industries with lower values of c have the "collusive price" constrained. The total deterrence of all cartels occurs when $\omega \geq 1$. Considering that the most realistic scenario is the intermediate one we conclude:

- For a given $1 > \omega > 1/2$, the higher is the degree of product homogeneity the higher is the price constraining, *ceteris paribus*;
- For a given $1 > \omega > 1/2$, a group of cartels with a high degree of product differentiation is not affected;
- The total deterrence occurs at the same stage, when $\omega \geq 1$.

The line ω is shifted upwards by an increase in the probability of detection (α) or by a higher penalty setting (f). Therefore, tougher antitrust policies help to constrain even more cartels with similar products (already constrained), as well as impact cartels with products more differentiated.

3. Conclusions

The impact of antitrust enforcement on cartel behavior is an important issue for antitrust researchers and policy makers. Such information is essential for guiding the public enforcement of competition law.

An important source of industry distinction is the degree of product differentiation. Many studies analyzed the impact of product differentiation on the cartel stability, but as far as we know none have studied the effects of antitrust enforcement in this context. We conclude that the antitrust enforcement (represented by the probability of detection and severity of fines) is more effective in constraining the "collusive price" when products are more homogeneous. However, the total deterrence of cartels occurs at the same point in all industries.

As a suggestion, the impact of self-report policies (such as leniency programs and cartel settlements) on different types of industry is an important topic of discussion nowadays. The understanding of this type of enforcement on different industries is also a good indication for future studies.

4. References

ALBÆK, S.; LAMBERTINI, L. Collusion in differentiated duopolies revisited. *Economics Letters*, v. 59, n. 3, p. 305-308, 1998.

BAKER, J. B. Product Differentiation through Space and Time: Some Antitrust Policy Issues. *Antitrust Bulletin*, v. 42, p. 177-196. 1996.

CHANG, M. The effects of product differentiation on collusive pricing. *International Journal of Industrial Organization*, v. 9, n. 3, p. 453-469, 1991.

DENECKERE, R. Duopoly supergames with product differentiation. *Economics Letters*, v. 11, n. 1-2, p. 37-42, 1983.

FRÜBING, S.; POLK, A. Product Differentiation, Leniency Programs and Cartel Stability. Berlin Institute for International Business Studies (BIIPS), Working Paper n.3. 2016.

HOUBA, H.; MOTCHENKOVA, E.; WEN, Q. Competitive prices as optimal cartel prices. *Economics Letters*, v. 114, n. 1, p. 39-42, 2012.

IVALDI, M.; JULLIEN, B.; REY, P.; SEABRIGHT, P.; TIROLE, J. The economics of tacit collusion: implications for merger control. In: *The Political Economy of Antitrust*. Emerald Group Publishing Limited. P. 217-239. 2007.

ROSS, T. W. Cartel stability and product differentiation. *International Journal of Industrial Organization*, v. 10, n. 1, p. 1-13, 1992.

ROTHSCHILD, R. On the sustainability of collusion in differentiated duopolies. *Economics Letters*, v. 40, n. 1, p. 33-37, 1992.

SONG, R.; WANG, L. F. S. Collusion in a differentiated duopoly with network externalities. *Economics Letters*, v. 152, p. 23-26, 2017.

SPAGNOLO, G. Leniency and Whistleblowers in Antitrust. In: BUCCIROSSI, P. (ed) *Handbook of Antitrust Economics*, Cambridge, MIT Press. 2008. p. 259-304.

EVALUATING THE BRAZILIAN LENIENCY PROGRAM EFFECTIVENESS

Abstract: The main objective of this paper is answering the following question: is the Brazilian Leniency Program effective in fighting cartels? The theoretical model provides the long-run prediction about an effective antitrust policy implementation, which is tested in a context of survival analysis. We estimate a competing risk model for cartels judged between 1996 and 2017, allowing the cartel to end naturally or by an antitrust intervention. We found that the Brazilian Leniency Program is effective in increasing the hazard of dissolution of cartels in the long-run in comparison to the short-run. As fighting cartels is a major concern of Brazilian antitrust authority, the understanding of leniency program effects becomes a key task to promote a competitive environment and avoid criminal activities.

JEL codes: L41, K21, C41

1. Introduction

Hardcore cartels[30] are known as the most harmful anticompetitive conduct. Either by the price increasing or other type of agreement (market division, rotation bids in procurements and so on) they reduce the competition, which tends to increase the price, reduce the allocative efficiency and harm the consumers. In the medium/long-run they also tend to decrease the incentives to competitive gains, as costs reductions and innovations. Thereby, fighting cartels is a major concern of antitrust authorities around the world.

One of the main problems regarding cartels is the fact that agreements are made in a discrete mode, thus it is hard to notice it, prove it and punish the members. As noted by Brisset and Thomas (2004), since they are illegal, cartels often organize clandestine meetings and communication, making detection very hard.

Recently, a new tool for fighting cartels was released by many countries, the leniency programs. They aim at reducing the sanctions against a cartel member that reports the infringement to the antitrust authority. Harrington (2008) differentiates two main effects of these policies: deterrence effect (preventing aspect) and desistance effect.

[30] A hardcore cartel is a well-structured collusion, in which there is an explicit coordination. It is the opposite of tacit collusion.

The first one says that leniency programs can deter cartel formation *ex-ante* either by making it unprofitable or making collusion unstable. The second one states that leniency programs can reduce the incentives to maintain an agreement (after the cartel formation) by expanding the set of future states for which the cartel collapses.

As informed by Harrington (2008), a well-designed leniency program was first implemented in United States of America (USA) in 1993, in spite that an amnesty program to fight antitrust issues was in course since 1978. The European Commission introduced its own leniency program in European Union (EU) in 1996. Even though leniency programs have been changed and improved over the years, Spagnolo (2008) notes the main differences between USA and EU policies. In the first one the cartel ringleader cannot obtain leniency, which is allowed by the latter. In EU the program offers milder forms of leniency also to all other firms that are not the first to come forward, while in USA only the first can be grant. In the USA there is individual liability for cartel infringements and therefore a correspondent Individual Leniency Policy that complements the Corporate Leniency Policy, which does not exist in EU.

Actually, a large number of countries have been adoptin leniency programs, generally inspired by the USA and EU policies. Spagnolo (2008) denoted it as "*the leniency revolution*", in which traditional ways of investigation (as buyer's complaints, audits and dawn raids) started to be replaced by self-reporting mechanisms.

The impact of leniency policies on collusion and bidding rings has become an important field of study in industrial organization. Some papers make use of statistical and econometric methods to verify the effectiveness and incentives generated by leniency programs. However, two obstacles arise in this context. The first one is the lack of data, since generally leniency agreements are confidential (at least while in progress) and hard to access. The second one is highlighted by Harrington and Chang (2009): due to their illegality, cartels hide themselves, thus only the population of discovered cartels is observed. For example, suppose that an antitrust policy has reduced the rate of cartel formation. By consequence, a lower rate of cartels is discovered due the less number of cartels in the economy, which can indicate that the policy was ineffective (less cartels are discovered and punished). It occurs precisely because only the population of discovered cartels is known.

To deal with this problem the empirical literature has developed hypothesis about the cartel behavior and cartel formation before and after the leniency program introduction, generally supported by theoretical models and discussions. Important

examples are Brenner (2009), Miller (2009) and Zhou (2016). In Pinha *et al.* (2016) there is a relevant review of literature regarding empirical papers on leniency policies.

In this context, this paper focuses on a main question: is the Brazilian Leniency Program effective in fighting cartels? According to CADE (2017), until 2017 more than eighty agreements were signed, but the number of agreements *per se* does not mean success or failure. A few number of agreements may mean success just because the leniency program is deterring collusion, but also can mean failure because it is not detecting cartels. In the same way, a high number may represent effectiveness in detection but ineffectiveness in deterring. As the total number of cartels in Brazil (and worldwide) is unknown, there is no parameter to compare if a leniency program is successful or not, hence the importance of other types of analysis. The effectiveness of Brazilian leniency Program implementation will be tested relying on Zhou (2016) predictions about cartel duration and hazard dissolution of cartels[31].

This paper provides new and relevant information on the Brazilian Leniency Program effectiveness[32]. Also, it contributes to the literature by presenting a robust estimation regarding statistical techniques of survival analysis. As fighting against collusion is a major concern of Brazilian antitrust authorities, the understanding of leniency program effects becomes a key task in the sense to promote a competitive environment and avoid criminal activities.

The organization of the paper is as follows. In Section 2 we talk about the Brazilian antitrust law and its peculiarities in comparison to other countries and regions. Section 3 contains the theoretical model and Section 4 presents the empirical framework. Next, we have the results and discussion in Section 5 and the conclusions in Section 6. Finally, the paper ends with the appendix and references.

2. The Brazilian antitrust law and its peculiarities

[31] We expose the theoretical predictions in the theoretical framework.

[32] As far as we known, only Lima *et al.* (2017) did something similar, however they focused on Brenner (2009) discussions about the influence of this policy on the revealed information, costs of investigation, cartel duration and the number of discovered cartels. When estimating the cartel duration model they define arbitrarily the short-run, do not consider the possibility of cartel ending for more than one cause and do not use robust methods of survival analysis estimation.

The Brazilian Leniency Program was adopted in the year 2000 by the Law nº 10.149/00. The agreement was done through the former Secretariat for Economic Law (*Secretária de Direito Econômico – SDE*) and judged by the Administrative Council for Economic Defense (*Conselho Administrativo de Defesa Econômica -CADE*). The first agreement was signed in 2003.

The Brazilian System of Competition Policy (*Sistema Brasileiro de Defesa da Concorrência – SBDC*) was changed in 2011, when the Law nº 12.529/2011 replaced the former Law nº 8.884/1994. It started to contain the rules that govern the current Brazilian Leniency Program until nowadays. In addition, the SDE was extinguished, thus the SBDC is now lead by CADE. The new Brazilian Leniency Program is similar to the previous one, except for three main changes highlighted by CADE (2016): the agreement is done directly by CADE; the cartel leader can be the leniency applicant (it was not allowed before); now the agreement may result in criminal immunity.

According to Martinez (2015), the Brazilian Leniency Program was inspired by the USA antitrust policies, including the "winner-takes-all" approach. It means that only the first one to sign the agreement is granted. Based on the Law nº 12.529/2011, the others following requirements are: the applicant must confess the infringement; the applicant must cease its involvement in the antitrust violation; the applicant agrees to provide full, continuing and complete cooperation to CADE throughout the investigation; the cooperation results in the identification of other members of the conspiracy and in obtaining documents that evidence the antitrust violation; at the time the leniency applicant comes forward, CADE has not received sufficient information about the illegal activity to ensure the imposition of sanctions against the applicant.

Following the USA Corporate and Individual Leniency Program, companies and individuals can benefit from leniency, meaning that a corporation can avoid government fines and individuals can escape fines and prison sentences. It depends if the antitrust authority was previously aware of the illegal activity being reported. A full administrative immunity may be obtained if the antitrust authority was unaware, while the applicable penalty can be reduced by one-third to two thirds otherwise, depending on the effectiveness of the cooperation and the 'good faith' of the party in complying with the leniency letter (MARTINEZ, 2015). According to CADE (2017), 82 leniency

agreements were signed until 2017, even more if we count the additions and leniency plus[33] agreements.

Antitrust laws in Brazil have some peculiarities when compared to other countries. According to European Commission (2017), the fines in European Union reflect the gravity and duration of the infringement. The starting point for the fine is the percentage of a company's annual sales of the product concerned in the infringement (up to 30%). Then, this is multiplied by the number of years and months the infringement lasted. Aggravating circumstances (e.g. repeat offender) or attenuating circumstances (e.g. limited involvement) may increase or decrease the fine. In cartel cases, the fine is increased by a one-time amount equivalent to 15-25% of the value of one year's sales as an additional deterrent and the maximum level of fine is capped at 10% of the overall annual turnover of a company. Antitrust enforcement in USA is governed by the Sherman Act 1890 and its amendments. Harrison and Bell (2006) informs that since 2004 companies can be punished by corporate fines of up to U$100 million (the maximum amount was U$10 million before the 2004 amendment), and the penalty is set based on the pecuniary gain or loss resulting from the offense and/or plea agreements, in which the defendant plead guilty in exchange for concessions.

In Brazil, the Law 8.884/1994 established the following criteria related to corporate fines: fine of 1% up to 30% of the company gross revenue in the last year preceding the establishment of the administrative procedure, concerning the business activity branch in which the offense occurred, which will never be lower than the advantage obtained when it is possible to calculate. The Law no 12.529/2011 enactment modified the range of fines to 0.1% up to 20%, but almost all the cartel cases that are judged recently started before this Law. Some conditions affect the fine setting: the damage caused, the good faith of defendant, the defendant economic situation, among others. It is interesting to note that while in USA the maximum possible fine was increased, in Brazil it decreased. This is a controversial theme because while higher fines

[33] In the leniency plus, the candidate that cannot apply for the original leniency can be benefitted if cooperate. As informed by CADE (2016), this situation occurs when a candidate is not able to propose a leniency agreement related to a cartel that he was a member, but he has information to prosecute another cartel in a different market that he was also participating. If the antitrust authority was unaware about the second cartel, the candidate can receive all the leniency benefits from the second one and also partial benefits from the first.

may destabilize collusion due the fear of being caught, it can contribute with the cartel due the fear of self-report.

Another peculiarity is the length of the proceedings in Brazil. Martinez (2015) highlights that Brazilian competition law requires the corporate applicant to identify all the individuals to sign the leniency letter in order to be protected (which does not occur in USA) and also identify individuals working for other cartel members to be included as defendants in the investigation, resulting in a very large number of defendants. This significantly extends the length of the administrative proceedings. In addition, Brazil is known as a bureaucratic country where court decisions take too long. It also increases investigation and prosecution duration.

The economic environment is also important in the analysis of leniency policies effectiveness, mainly because it may affect the cartel formation, duration and stability. Rotemberg e Saloner (1986) argue that collusion is harder to sustain when the demand is relatively high. This is because when demand is high the benefit of a price undercutting is larger, i.e., a cartel member that reduces marginally its price will capture a larger share of the market. At the same time, the punishment from deviating is lower if the member predicts that demand will return to its normal level in the future. Therefore, the benefits of deviating tend to be higher than the expected punishment, which makes the collusion harder to sustain. Since the dynamics of the economy is distinct between Brazil, USA and Europe due internal and external factors, the consequences of the leniency program in Brazil may differ. For example, developed countries suffered more with the 2008 international crisis, while Brazil, China, India, among others emergent countries were less affected.

The empirical literature on leniency policies is recent and focuses on USA and EU leniency programs. Little is known about leniency programs effectiveness and how these policies work in practice, mainly related to emerging economies where antitrust policies were adopted later, such as Brazil. Furthermore, particular characteristics of antitrust laws and economic environment in each country may result in different conclusions about leniency effectiveness. Considering the characteristics of antitrust laws in Brazil, results may or may not confirm theoretical and empirical predictions.

3. The theoretical model

In Harrington and Chang (2009), the authors developed a theoretical model associating the total population of cartels (discovered and undiscovered) to the population of discovered ones. The objective is to verity how these populations are related by modelling the birth and death of cartels in heterogeneous industries, and then it is possible to infer the impact of an antitrust policy on the total population. Despite not having empirical tests, the authors use the First Order Stochastic Dominance (FOSD) to conclude that the implementation of an effective leniency program changes the parameters such that the rate of cartel detection is increased, which tends to elevate the average duration of discovered cartels in the short-run. In the long-run, the effect on the average duration of cartels is inconclusive, it may increase or decrease.

Zhou (2016) proposes a new theoretical model based on Harrington and Chang (2009), but instead of the FOSD he focuses on the hazard of dissolution of cartels. This is the theoretical model that supports this paper. From now on in this subsection we present the model as in Zhou (2016), while a detailed exposition is provided in the appendix.

The model relies on to the cartel duration and hazard dissolution of cartels. Basically, the leniency introduction changes some collusive patterns that will be tested later. Given the model assumptions, predictions relate the probability that a cartel survives for *t* periods conditional on the event that the cartel survives for at least *t* periods, i.e., the dissolution hazard of discovered cartels. The main idea is that a leniency program affects the hazard over time, i.e., it causes an exogenous change in the detection rate from σ_1 to σ_2, in which $\sigma_2 > \sigma_1$.

Let $s(t;\ \sigma, \theta)$ denote the steady-state share of cartels with a duration of *t* periods in a type θ industry under policy σ, in which $t \in \{0, 1, 2, \dots\}$. In $t = 0$ the industry θ is not cartelized, and $1 - \sum_{\hat{t}=0}^{t-1} s(\hat{t};\ \sigma, \theta)$ is the share that survive for at least *t* periods. The steady-state dissolution hazard of discovered cartels in industry type θ before the leniency program is expressed as the following:

$$h(t;\ \sigma_1, \theta) = \frac{s(t;\ \sigma_1, \theta)}{1 - \sum_{\hat{t}=0}^{t-1} s(\hat{t};\ \sigma_1, \theta)},\ t \in \{0, 1, 2, \dots\} \qquad (1)$$

The average steady-state dissolution hazard of discovered cartels before the leniency program adoption is given by:

$$\tilde{h}(t;\ \sigma_1) = \frac{\int_{\Theta_1} s(t;\sigma_1,\theta) f(\theta) d(\theta)}{1-\int_{\Theta_1} \sum_{\hat{t}=0}^{t-1} s(\hat{t};\sigma_1,\theta) f(\theta) d(\theta)}\ ,\quad t \in \{0,1,2,\dots\} \tag{2}$$

where Θ_1 is the set of industries in which collusion can be sustained before the leniency program. Equation (2) can be expressed as:

$$\tilde{h}(t;\ \sigma_1) = \int_{\Theta_1} \left[h(t;\ \sigma_1,\theta) \times \frac{\left(1-\sum_{\hat{t}=0}^{t-1} s(\hat{t};\sigma_1,\theta)\right) f(\theta)}{\int_{\Theta_1} \left(1-\sum_{\hat{t}=0}^{t-1} s(\hat{t};\sigma_1,\theta)\right) f(\theta) d(\theta)} \right] d(\theta) \tag{3}$$

Thus, $\tilde{h}(t;\ \sigma_1)$ in (3) is the weighted average of $h(t;\ \sigma_1,\theta)$ in (1), where the associated weight is the probability that a cartel with a duration of at least *t* periods is of type *θ*.

Let Θ_2 denotes the set of industries that are able of sustaining collusion after the leniency program, in which $\sigma_1 < \sigma_2$, then $\Theta_1 \supseteq \Theta_2$. It follows that when the detection rate improves, the measure of the set of industries able to sustain collusion is reduced. After the leniency program, formerly stable cartels in the set $\Theta_1 \setminus \Theta_2$ collapse immediately and the distribution of industries shifts from one level to another, as expressed in Expression (4):

$$\frac{\left(1-\sum_{\hat{t}=0}^{t-1} s(\hat{t};\sigma_1,\theta)\right) f(\theta)}{\int_{\Theta_1} \left(1-\sum_{\hat{t}=0}^{t-1} s(\hat{t};\sigma_1,\theta)\right) f(\theta) d(\theta)} \quad \text{to} \quad \frac{\left(1-\sum_{\hat{t}=0}^{t-1} s(\hat{t};\sigma_1,\theta)\right) f(\theta)}{\int_{\Theta_2} \left(1-\sum_{\hat{t}=0}^{t-1} s(\hat{t};\sigma_1,\theta)\right) f(\theta) d(\theta)} \tag{4}$$

However, in the short-run durations stay unadjusted for the remaining cartels, i.e., their dissolution hazard is unchanged. In the short-run, the average dissolution hazard shifts from $\tilde{h}(t;\ \sigma_1)$ to a new stage, as expressed in Equation (5):

$$\tilde{h}(t;\ \sigma_1;\sigma_2) = \int_{\Theta_2} \left[h(t;\ \sigma_1,\theta) \times \frac{\left(1-\sum_{\hat{t}=0}^{t-1} s(\hat{t};\sigma_1,\theta)\right) f(\theta)}{\int_{\Theta_2} \left(1-\sum_{\hat{t}=0}^{t-1} s(\hat{t};\sigma_1,\theta)\right) f(\theta) d(\theta)} \right] d(\theta) \tag{5}$$

The transition from the short-run to the new steady state involves the duration of the surviving cartels adjusting in each industry. The industry-level hazard shifts from the stage before the policy exogenous change to the new stage, as the following:

$$h(t;\ \sigma_1, \theta)\ \text{ to }\ h(t;\ \sigma_2, \theta) = \frac{s(t;\ \sigma_2, \theta)}{1 - \sum_{\hat{t}=0}^{t-1} s(\hat{t};\ \sigma_2, \theta)} \qquad (6)$$

In consequence, the average hazard readjusts, in the long-run, to the stage expressed by Equation (7):

$$\tilde{h}(t;\ \sigma_2) = \int_{\Theta_2} \left[h(t;\ \sigma_2, \theta) \times \frac{\left(1 - \sum_{\hat{t}=0}^{t-1} s(\hat{t};\ \sigma_2, \theta)\right) f(\theta)}{\int_{\Theta_2} \left(1 - \sum_{\hat{t}=0}^{t-1} s(\hat{t};\ \sigma_2, \theta)\right) f(\theta) d(\theta)} \right] d(\theta) \qquad (7)$$

Based on this framework, Zhou (2016) reaches two main results. The first proposition is on short-run effects of raising detection rate. If $\sigma_1 < \sigma_2$, then $\tilde{h}(t;\ \sigma_1) \geq \tilde{h}(t;\ \sigma_1; \sigma_2)$ for all $t \in \{0, 1, 2, \dots\}$. It means that an increase in the detection rate leads to an immediate fall in the average dissolution hazard of discovered cartels. Empirically, an increase in the average duration of detected cartels immediately following the introduction of a leniency program corresponds to improved deterrence capabilities. It occurs because "marginal cartels" that are about to collapse would not form *ex-ante*, resulting that the discovered ones are longer-lasting cartels.

The second proposition is about the long-run effects. If $\sigma_1 < \sigma_2$, then $\tilde{h}(t;\ \sigma_1; \sigma_2) \leq \tilde{h}(t;\ \sigma_2)$. After the immediate fall in the average hazard of discovered cartels following an increase in the detection rate, the hazard readjusts above the short-run levels. In practice, following the initial increase in average durations, a subsequent readjustment below short-run levels corresponds to improved destabilizing capabilities. This is because the formerly stable and long-lasting cartels dissolve faster, leading to a decline in observed average durations.

4. Empirical framework

4.1.The empirical method

The empirical literature on cartel duration and hazard dissolution is generally inserted in a context of survival analysis, based on hazard models[34]. According to Kleinbaum and Klein (2005), survival analysis makes use of a collection of statistical

[34] Important examples are De (2010) and Levenstein and Suslow (2011).

procedures for which the outcome variable of interest is *time until an event occurs*. In our case, the event of interest is the cartel dissolution.

Cox (1972) proposed the most common hazard model, the well-known *Cox Proportional Hazard Model*. It defines a semi-parametric hazard function to verify the impact of covariates on the hazard rate of some event to occur. However, this model analyzes only one cause of the event (one type of failure), for example the hazard rate of a cancer, of unemployment or the end of a collusive agreement. Zhou (2016) and Levenstein and Suslow (2011) highlights an important issue: a cartel can end for more than one reason. For instance, the reason may be internal factors as a betrayal or instability, so as an external factor, like an antitrust intervention (the antitrust authority discovers the cartel and punishes the members). We say that there is more than one type of failure that causes the event, known as *competing risks*. This name is because the failures are mutually exclusives, i.e. if one occurs the other cannot happen, thus they "compete" to be the one to cause the event.

The literature has developed some ways to deal with competing risks. According to Noordzij *et al*. (2013), there is a consensus that the model proposed by Fine and Gray (1999) is the most appropriate method to use. This is because there is a direct relationship between the covariates and the *cumulative incidence function (CIF)* by the subdistribution hazard models, as presented from hereon.

Assume that T is the survival time of the cartel, while t is any specific value of T. According to Kleinbaum and Klein (2005), the hazard function $h(t)$ gives the instantaneous potential per unit time for the event to occur, given that the individual has survived up to time t. Mathematically, it is expressed by the following:

$$h(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T < t + \Delta t | T \geq t)}{\Delta t} \tag{8}$$

It means that $h(t)$ equals the limit, as Δt approaches zero, of a probability statement about survival, divided by Δt (a small interval of time). It is also denoted as *conditional failure rate*.

The framework above expresses the hazard function when we have one type of failure. Fine and Gray (1999) propose the following specification in a competing risk context for the failure type 1, as shown in Equation (9):

$$h_1(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T < t+\Delta t | (T \geq t,\ if\ failure = 1) \cup (T < t,\ if\ failure \neq 1)}{\Delta t} \quad (9)$$

This expression is known as the *subdistribution hazard function* for the failure type 1, while the expression is analogous for other failures. As informed by Austin and Fine (2017), the subdistribution hazard function for a given type of failure of an event is defined as the instantaneous rate of occurrence of that failure in subjects who have not yet experienced an event of that type of failure. In other words, it considers the hazard in those subjects who are either currently event-free or who have previously experienced a competing failure. The CIF is obtained by the following:

$$CIF_1(t) = 1 - \exp[-H_1(t)] \quad (10)$$

In which $H_1(t) = \int_0^t h_1(t)\, dt$. As highlighted by Austin and Fine (2017), the CIF describes the incidence of the occurrence of an event for a specific type of failure while taking competing risks into account.

The estimation of the subdistribution hazard function is similar to the Cox Proportional Hazards Model. The regression is the following:

$$h_1(t|\boldsymbol{x}) = h_{1,0}(t|\boldsymbol{x})\exp(\boldsymbol{x\beta}) \quad (11)$$

In which $\boldsymbol{x}$ in Equation (11) is the vector of explanatory variables and $\boldsymbol{\beta}$ the vector of coefficients. The term $h_{1,0}(t|\boldsymbol{x})$ is the baseline subhazard, defined when covariates are set to zero. This term is left unspecified, that is why this model (and Cox model) is known as semi-parametric. The estimation of β produces the exponentiated coefficients $exp(\boldsymbol{x\beta})$, also known as *subhazard ratios*. They provide the magnitude of the relative change in the subdistribution hazard function related to a one-unit change in the given covariate. As in Austin and Fine (2017), the estimation of (11) measures the relative change in the instantaneous rate of the occurrence of the event in those subjects who are event-free or who have experienced a competing failure. When the subhazard ratio is

greater than one the impact generated by the covariate on the subdistribution hazard function is positive, otherwise (lower than one) the impact is negative[35].

The objective is the estimation of the theoretical predictions presented previously. They are related to the natural death of cartels, so this is the failure of interest (the competing risk failure is the antitrust intervention, as explained later). To test the short-run proposition we would need to compare the hazard of dissolution of cartels that was formed and ended before the Brazilian Leniency Program introduction to the hazard of dissolution of cartels that started before and ended after the policy implementation. However, we have very few cases of cartels that have formed and ended before the year 2000, turning this estimation unfeasible. On the other hand, the long-run prediction requires the comparison of the hazard of dissolution in cartels that started before and ended after the policy implementation to cartels that started and ended after the policy adoption. This is the one we are about to test.

4.2.The data

The data were collected from the files that compose the administrative procedures of cartel cases in SBDC. These files are open access and can be obtained in the CADE (2018). The sample is a cross-section of 68 cartel cases that were judged between 1996 and 2017. Only the classic cartel cases were considered, in which competitors combine the actions to reduce the competition. These are the cases where a cartel member can apply for leniency[36]. The cartel cases include gas station cartels, cement cartel, stone and sand cartels and also some famous cases worldwide as the vitamins cartel. We explain how the covariates are built hereafter.

The dependent variable is the cartel duration in months (*duration* from hereon). We assume the agreement can end for two reasons: naturally or by an antitrust intervention, thus these are the competing risks failures. The information about the cartel

[35] It occurs because the subhazard ratios are exponentiated coefficients. The non-exponentiated coefficients (β) are obtained taking the natural logarithm. Suppose a general x, when $\exp(x) > 1$ we have $ln[exp(x)]$ positive, and when $\exp(x) < 1$ we have $ln[exp(x)]$ negative.

[36] We consider that the Brazilian Leniency Program only impact these cartels. There are many cases where an association, union or trade association influence some class of workers or firms to act together, which can be considered a cartel, however in these cases the only the association is punished. There is no room for leniency in these cases.

duration is not clear and obvious, therefore we needed to check a lot of files and set some assumptions. The start date is the month informed by the files or January of the year informed when the reference is the year (for instance, if the cartel started in 1999, we consider Jan/1999). The cartel ended naturally when is explicitly informed by the files regarding meetings, phone calls, coordinated actions or procurements and the end date is before the beginning of the investigation. We assume that the cartel ends by the antitrust intervention if there is no information of a previous break when the investigation begins. In these cases, we consider the end date the month in which the administrative procedure was registered in SBDC[37].

The explanatory variables are the ones that may affect the cartel hazard of dissolution. The main covariate is the dummy that represents the long-run prediction (*long run dummy* from hereon). It takes the value of zero if the cartel started before December 2000 (when the law was enacted) and ended after this date, while the value is one if the cartel started and ended after this date. A significant and greater than one coefficient means that the Brazilian Leniency Program was effective in increasing the hazard of dissolution of cartels in the long-run in comparison to the short-run, as predicted in the theoretical model.

The other explanatory variables are divided in three categories: cartel characteristics, severity of the anti-cartel enforcement and economic environment. Related to the cartel characteristics we have four variables: 1) number of companies and persons involved in the infringement (*number of members* hereafter) - it is expected that the higher the number of participants riskier is the agreement; 2) number of subsections of the Law 8.884/94 in which the cartel is involved (*number of subsections* hereafter) - we expect that the higher the number of violations higher is the risk of a break; 3) categorical variable informing the range of the relevant market where the cartel operated (*relevant market* hereafter) - we expect that the higher is the area of act greater is the hazard of dissolution; 4) dummy informing if the cartel acted in a normal market or in procurements (*market or procurement dummy* hereafter) - no *ex-ante* predictions about the impact on the hazard of dissolution.

Regarding the severity of anti-cartel enforcement, the variable is the number of cases judged in the year of cartel ending (*number of cases* from hereon). We expect that

[37] As a robustness check, we realized the same statistical procedures considering the final judgment date as the cartel end date. However, results were quite similar as the ones presented below.

the higher is the severity of antitrust acting higher is the risk of dissolution. Finally, the economic environment is represented by a dummy that takes the value one if the cartel went through the crisis of 2008 (started before September 2008 and ended after this date), and zero otherwise (*crisis of 2008 dummy* hereafter)[38]. As Rotemberg e Saloner (1986) argue that collusion is harder to sustain when the demand is relatively high, we expect that if the cartel went through the crisis the hazard of dissolution decreases (it is easy to keep the agreement in a recession period).

5. Results and discussion

Table 1 presents the descriptive statistics of the discrete covariates.

Table 1. Descriptive statistics of discrete covariates

	Mean	**Standard dev.**	**Min.**	**Max.**
Duration (months)	50.91	56.70	1	272
Number of cases	1.59	2.63	0	13
Number of subsections	5.25	2.27	2	11
Number of members	12.93	9.72	2	51

Source: Research Results.

It is worth noting the variability of cartel duration, i.e., a standard deviation higher than the mean, while the minimum duration is one month and the maximum duration is 272 months. Another important information is that a relevant number of companies and persons are involved in the cartel on average. Regarding the dummies and the categorical variable we have the following: *long-run dummy* - 38% of the cartels started and ended before the Brazilian Leniency Program adoption (value zero) and 68% started before and ended after the implementation (value one); *market or procurement dummy* – 78% of cases were in normal markets (value one), while 22% operated in procurements (value zero); *crisis of 2008 dummy* – around 21% of the sample went through the crisis start date (value one), while 79% of cartels started and ended before this date or started and ended after this date (value zero); *relevant market* – around 57%

[38] This date is due the bankruptcy of Lehmann Brothers in September 2008.

of collusive agreements operated in cities (value one), 13% in states (value 2), 21% in the whole country (value three) and 9% internationally (value four).

Now we proceed to the main results. Table 2 shows the subhazard ratios and Table 3 the non-exponentiated coefficients (that inform if the impact is positive or negative). As the main interest is on the impact of covariates on the hazard of dissolution we focus on the subhazard ratios. The Wald test indicates a *p-value* of 0.00, which denotes the joint significance of variables in explaining the hazard model. The tables are the following:

Table 2 – Subdistribution hazard model estimates – subhazard ratios

	Subhazard ratio	**z-statistic**	**p-value**
Long-run dummy	2.35** (0.90)	2.24	0.02
Number of members	1.00 (0.02)	0.03	0.98
Number of subsections	1.00 (0.08)	-0.06	0.95
Relevant Market	1.05 (0.18	0.29	0.77
Market or procurement dummy	0.24*** (0.08)	-4.03	0.00
Number of cases	1.09 (0.09)	1.12	0.265
Crisis of 2008 dummy	0.18*** (0.10)	-2.99	0.00

Note: Standard deviation in parentheses. ***0.1% of significance ** 0.5% of significance.

Source: Research results

Table 3 – Subdistribution hazard model estimates – non-exponentiated coefficients

	Coefficients	**z-statistic**	**p-value**
Long-run dummy	0.86** (0.38)	2.24	0.02
Number of members	0.00 (0.23)	0.03	0.98
Number of subsections	0.00 (0.08)	-0.06	0.95
Relevant Market	0.05 (0.17)	0.29	0.77
Market or procurement dummy	-1.44*** (0.37)	-4.03	0.00

Number of cases	0.09 (0.08)	1.12	0.265
Crisis of 2008 dummy	-1.73*** (0.58)	-2.99	0.00

Note: Standard deviation in parentheses. ***0.1% of significance ** 0.5% of significance.

Source: Research results

As already mentioned, the best way to interpret the subhazard ratios in Table 2 is a relative change in the instantaneous rate of the occurrence of the event due the failure of interest (natural death of cartels) associated with a 1-unit change in the given covariate.

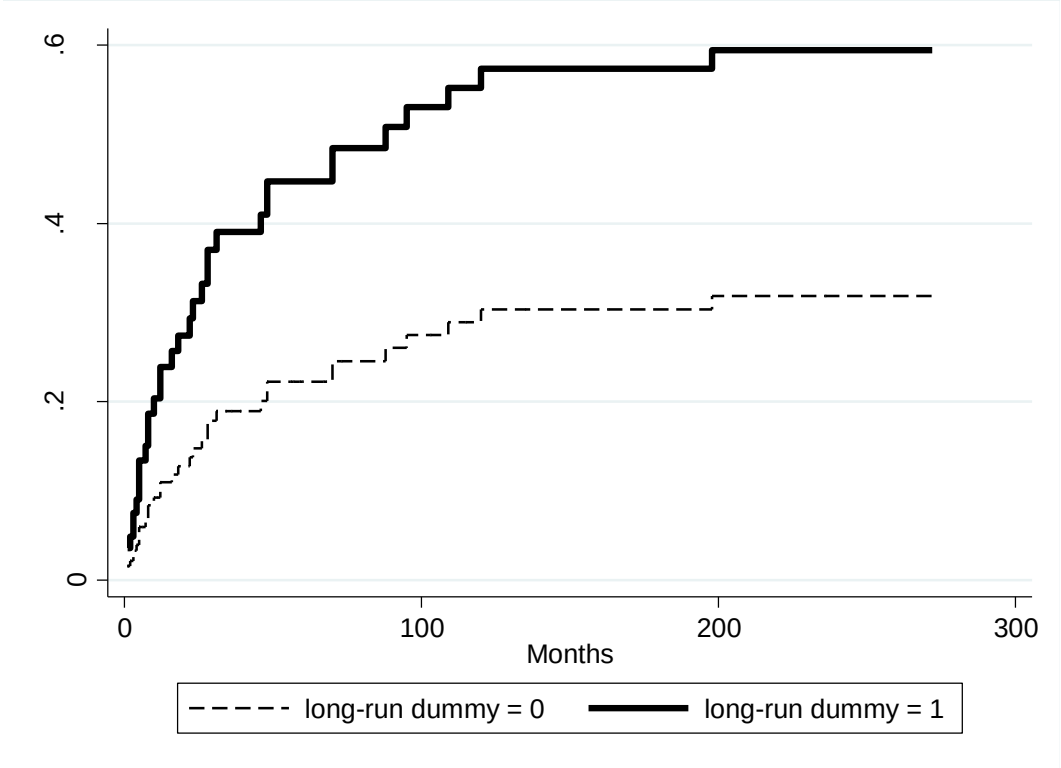
The covariates *number of members, number of subsections, relevant market* and *number of cases* are not significative, i.e., three explanatory variables related to cartel characteristics and the explanatory variable related to the severity of anti-cartel enforcement. On the other hand, the *market or procurement dummy* is significative and negatively associated with the hazard of dissolution. Iif the cartel operates in the market instead of procurements it reduces the instantaneous rate of dissolution, meaning that market cartels are less risky of ending naturally. A possible explanation is that normal cartels tend to operate indefinitely and with more ways to keep the agreement solid and stable, including concealment acts, periods of no contact between the members, among other acts. Procurement cartels require the existence of procurements (if there is no procurement the cartel ends naturally) and it is harder to find ways to keep the agreement stable (there is not too much to do but keep in contact and combine the bids), turning it riskier.

The explanatory variable *crisis of 2008 dummy* is also significant and negatively related to the hazard of dissolution, as predicted previously. It means that collusive agreements that went through the crisis are less risky to end naturally, mainly because the change of economic environment strengthened the cartel by reducing the gains of deviation.

Now we focus our attention to the variable of main interest. The *long-run dummy* subhazard ratio is significant and greater than one, thus it impacts positively the risk of dissolution instantaneous rate. It means that the Brazilian Leniency Program was effective according to the long-run predictions. More specifically, a collusive agreement that started and ended after the policy implementation is associated to an increase of 135% on the instantaneous rate of cartel dissolution in comparison to cartels that started before and ended after the Brazilian Leniency Program adoption, everything else constant.

As highlighted by Austin and Fine (2017), an alternative way to look at this result is to interpret the covariates as influencing the CIF. It allows the comparison between the cumulative incidence of the occurrence of a natural cartel break in any covariate setting. As the main interest is the *long-run dummy* we estimate two CIF curves, one for each dummy value. The other explanatory variables are set at the mean over the data set. The CIF curves are represented in Figure 1 as the following:

Figure 1. The Cumulative Incidence Functions (CIF) for the *long-run dummy* values



Source: Research results

When the dummy is one the CIF is always higher than when the value is zero, which corroborates the previous result, i.e., the hazard of natural dissolution is increased when the dummy is one. For cartels that started before and ended after the Brazilian Leniency Program adoption (*long-run dummy* = 0) the risk of a cartel break within 50 months is near 20%, and within 200 months roughly 25%, *ceteris paribus*. On the other hand, for cartels that started and ended after the policy implementation (*long-run dummy*

= 1) the risk of dissolution is almost 40% within 50 months, 45% within 100 months and nearly 60% within 200 months.

We found that the Brazilian Leniency Program was effective in increasing the cartels hazard of dissolution in the long-run in comparison to the short-run, as predicted by the theoretical model when an effective antitrust policy is implemented. To sum up, this policy is efficient in destabilize cartels, which is something desirable in any antitrust enforcement. In comparison to related papers, our results corroborate what was found in Miller (2009) for USA, Choi and Hahn (2014) for South Korea, Zhou (2016) for EU[39] (after the 2002 reform) and USA and Yusupova (2017) for Russia (after the 2009 reform).

Two worth noting observations are derived from this result. The first one is that the literature about the USA Corporate Leniency Program is consensual about the policy effectiveness, which is not true for the one related to the EU Leniency Program[40]. Since the Brazilian Leniency Program is based on the USA we can conclude that it was a positive choice. Another issue is that the Brazilian Leniency Program went through important changes in 2011, as informed in the Introduction. Our results are related to the policy implementation, unfortunately we cannot conclude anything empirically regarding these changes due the lack of data. Nevertheless, we do not have reasons to believe that the changes were harmful, since including criminal liability and allowing the leader to sign the leniency agreement tend to improve the policy destabilizing capacities.

6. Conclusions

Policy evaluation is an essential issue in empirical economic analysis. In anti-cartel policies the idea is to increase the rate of cartel detection as well to decrease the cartel formation by destabilization and/or non-profitability. The main problem is that the total number of cartels is unknown, i.e., only the discovered ones are observable, so the literature had to develop models that allow the inference on the total population of cartels from the information of the visible ones.

[39] Check Pinha *et al.* (2016) for a detailed presentation about the empirical literature.

[40] Brenner (2009) finds that EU Leniency Program is effective in some ways (it increases the amount of information revealed to the antitrust authority and reduces the investigation costs), but it is not effective in changing the cartel duration patterns. De (2010) finds no effectiveness.

The starting point of the paper is the short-run and long-run theoretical predictions. Due the lack of data the short-run test is unfeasible, thus we focused our attention on the long-run hypothesis. We found that the Brazilian Leniency Program was effective in increasing the hazard of dissolution of cartels in the long-run.

Our results contribute to the understanding of this policy in Brazil, however the debate is far from over. There are several topics of discussion nowadays regarding the leniency program in Brazil and worldwide in order to improve its effectiveness. We can cite the interplay between the Brazilian Leniency Program and the private damage claims (restitution for damage done). Since the lack of a well-established set of rules regarding damage claims may be harming the effectiveness of the Brazilian Leniency Program, either by discouraging the wrongdoers from applying for leniency in already formed cartels or by not being threatening enough to deter the cartel formation. Another topic of discussion is the length of the proceedings in Brazil, which tends to harm the effectiveness of anti-cartel policies. Our point is that even proving the Brazilian Leniency Program effectiveness the idea is to improve its efficiency even more.

The main limitation of this paper is the impossibility of estimating the short-run hypothesis and testing some predictions about the Law nº 12.529/2011. This Law made an important revision and stated the new competition policy in Brazil not only for anti-cartel enforcement, but also for other type of topics associated to antitrust (mergers, uniform conduct and so on). As a suggestion for future papers, we indicate the analysis of this Law as soon as the data allow.

7. References

AUSTIN, P. C.; FINE, J. P. Practical recommendations for reporting Fine-Gray model analyses for competing risk data. *Statistics in Medicine*, V. 36, p. 4391-4400. 2017.

BRENNER, S. An Empirical Study of the European Corporate Leniency Program. *International Journal of Industrial Organization*. V. 27, nº 6 , p. 639–645. 2009.

BRISSET, K.; THOMAS, L. Leniency Program: A New Tool in Competition Policy to Deter Cartel Activity in Procurement Auctions. *European Journal of Law and Economics*. V. 17, Nº 1, p. 5-19. 2004.

CADE (*Conselho Administrativo de Defesa Econômica*). 2016. Guia – Programa de Leniência Antitruste do CADE. Available in: http://www.cade.gov.br/acesso-a-informacao/publicacoes-institucionais/guias_do_Cade/guia_programa-de-leniencia-do-cade-final.pdf. Accessed in: December 10, 2017.

CADE (*Conselho Administrativo de Defesa Econômica*). 2017. Programa de Leniência. Available in: http://www.cade.gov.br/assuntos/programa-de-leniencia. Accessed in: January 2, 2018.

CADE (*Conselho Administrativo de Defesa Econômica*). 2018. Processos. Available in: http://www.cade.gov.br/assuntos/processos-1. Accessed in: January 15, 2018.

CHOI, Y. J.; HAHN, K. N. How does a Corporate Leniency Program Affect Cartel Stability? Empirical Evidence from Korea. *Journal of Competition Law & Economics*, v. 10, nº4, p. 883-907. 2014.

COX, D. R. Regression Models and Life-Tables. *Journal of the Royal Statistical Society.* Vol. 34, No. 2, p. 187-220. 1972.

DE, O. Analysis of Cartel Duration: Evidence from EC Prosecuted Cartels. *International Journal of the Economics of Business*. Vol. 17, n. 1, p. 33-65. 2010.

EUROPEAN COMISSION. 2017. Antitrust - An overview. Available in http://ec.europa.eu/competition/antitrust/overview_en.html. Accessed in December 20, 2015.

FINE, J.P.; GRAY, R.J. A proportional hazards model for the subdistribution of a competing risk. *Journal of American Statistics Association*. V.94, p. 496–509. 1999.

HARRINGTON, J. E. Optimal Corporate Leniency Programs. *The Journal of Industrial Economics,* V. 56, Nº 2, p. 215–246. 2008.

HARRINGTON, J. E.; CHANG, M. Modeling the Birth and Death of Cartels with An Application to Evaluating Competition Policy. *Journal of European Economic Association*, V. 7, Nº 6, p. 1400-1435. 2009.

HARRISON, G.; BELL, M. Recent enhancements in antitrust criminal enforcement: bigger sticks and sweeter carrots. *Houston Business and Tax Law Journal*. V. 6, Nº2, p.207-240. 2006.

KLEINBAUM, D. G.; KLEIN, M. Survival Analysis: A Self-Learning Text. 2º edição, Springer. 2005. 700 p.

LEVENSTEIN, M. C.; SUSLOW, V. Y. Breaking Up Is Hard to Do: Determinants of Cartel Duration. *Journal of Law and Economics*, V. 54, Nº 2, p. 455-92. 2011.

LIMA, F. M. S.; SALGADO, L. H.; FIUZA, E. P. S. Leniency and cooperation programs in brazil: an empirical analysis from 1994 to 2014. Available in: https://lawle2014.files.wordpress.com/2017/10/salgado-artigo-fl-lhs-epsf-final-version.pdf. Accessed in: January 10, 2018.

MARTINEZ, A. P. Challenges Ahead of Leniency Programmes: The Brazilian Experience. *Journal of European Law and Practice*. V. 6, Nº 4, p. 260-267. 2015.

MILLER, N.H. Strategic Leniency and Cartel Enforcement. *American Economic Review*. V. 99, Nº 3, p. 750–768. 2009.

NOORDZIJ, M.; LEFFONDRÉ, K.; VAN STRALEN, K. J.; ZOCCALI, C.; DEKKER, F. W.; Jagger, K. J. When do we need competing risk survival analysis in nephrology? *NDT Perspectives*. V. 28, p. 2670-2677. 2013.

PINHA, L. C.; BRAGA, M. J.; CORREIA, G. A. S. A efetividade dos programas de leniência e o contexto brasileiro. *Revista de Defesa da Concorrência*, v.4, n.1, p. 133-152. 2016.

ROTEMBERG, J. J.; SALONER, G. A Supergame-Theoretic Model of Price Wars during Booms. *American Economic Review,* V. 76, Nº 3, p. 390-407. 1986.

SPAGNOLO, G. Leniency and Whistleblowers in Antitrust. In: BUCCIROSSI, P (ed). *Handbook of Antitrust Economics*, Cambridge, MIT Press. 2008. p. 259-304.

ZHOU, J. Evaluating Leniency with Missing Information on Undetected Cartels: Exploring Time-Varying Policy Impacts on Cartel Duration. Working paper, 2016. Available in: https://www.ssrn.com/abstract=1985816. Accessed in: January 4, 2018.

YUSUPOVA. G. Can the leniency program deter collusion in young competition jurisdiction of transition economy*? International Journal of Economic Policy in Emerging Economies*, V. 10, n. 4, p. 383-406. 2017.

8. Appendix

In this appendix, we present the theoretical model developed by Zhou (2016) in details. Consider a population of oligopolistic industries in which N identical firms play infinitely repeated Prisioner's Dillema in each industry. The collusive profit in each period is stochastic and denoted by π. This profit is realized if all firms of the industry cartelize, if not they compete and earn $\alpha\pi$. Without loss of generality α is normalized to $\alpha = 0$. A cartel member earns $\theta\pi$ ($\theta > 1$) if unilaterally deviates from the price agreed, this the industries are differentiated by θ. The value of θ derives from a F distribution bounded by $[\underline{\theta}, \overline{\theta}]$ and the probability density function f. The profit π is given by a G distribution limited by $[\underline{\pi}, \bar{\pi}]$ and the probability density function g. Firms observe the profit before taking the decision in the beginning of each period, while the discount factor is the same for all and given by δ, such that $0 < \delta < 1$.

In the beginning of each period an industry may be cartelized or not. The industry begins a new period cartelized if it went through the end of the previous period cartelized, while in industries that did not form the collusion in the previous period may realize the collusive agreement in the beginning of the new period with probability p, such that $0 < p < 1$.

Consider y^0 as the firm pay-off when the industry is cartelized, while w^0 is the firm pay-off when the industry is competitive. If the industry is not cartelized the agreement is may be done with probability p and each firm earns y^0, while with probability $1-p$ they keep competing and each one earns zero in the current period and w^0in next ones. Mathematically:

$$w^0 = (1-p)\delta w^0 + py^0 \tag{12}$$

The antitrust enforcement is a pair of parameters $\langle \sigma, \gamma \rangle$, in which $\sigma \in (0,1)$ is the probability of detection and punishment by the antitrust authority in the end of each period. In this case, the fine that each member pays is γy^0, such that $\gamma > 0$, thus γ is interpreted as a "penalty multiplier".

Now we define the collusive pay-offs. Assume that a cartel is formed and each member earns π. If they respect the agreement each one earns π in the current period and with probability $1-\sigma$ they escape from detection, so the pay-off is y^0 for the next periods. With probability σ they are detected, each firm pays a fine of γy^0 in the end of the period and expects the pay-off of w^0 for the future. When the firm unilaterally deviates it earns $\theta\pi$ currently and w^0 from thereon, since the cartel will not form again after the betrayal. Nevertheless, in the period that the deviation occurred the firm can be detected with probability σ and be forced to pay the fine γy^0 . This is because the firm realized the collusive agreement, despite of the deviation. It is worth noting that the firms do not use the grim-trigger strategy (keep colluding as soon as no one deviates, otherwise never collude again), i.e., in this framework when there is a deviation the cartel is undone, however a new agreement is possible for the future.

Harrington and Chang (2009) and Zhou (2016) propose the pay-offs rescaling, such that $\mathrm{y} = (1-\delta)y^0$ and $\mathrm{w} = (1-\delta)w^0$. This technique is used to facilitate the math and does not change the conclusions, it just alters the pay-off scale. For instance, if $y^0 = 5$ and $\delta = 0.2$ we have $\mathrm{y} = 4$, but if the original pay-off is the double ($y^0 = 10$) and maintaining the same discount rate we have $\mathrm{y} = 8$, also double the initial value. Intuitively, it is possible to think that these rescaled pay-offs denote that firms do not compare only the pay-offs of collude or not, but the difference between the pay-off in t and the discounted pay-off in $t+1$. As y^0 and w^0 are the same in every period the change

is just a matter of scale. Multiplying both sides of equation (12) by $(1-\delta)$ and solving for w we have:

$$w = \frac{py}{1-\delta(1-p)} \tag{13}$$

In this way, it is possible to have the following pay-offs as a function of y, as presented hereafter. The cartel is sustainable if the pay-off of respecting the agreement exceeds the pay-off of deviation:

$$\pi + \delta[(1-\sigma)y^0 + \sigma(w^0 - \gamma y^0)] \geq \theta\pi + \delta(w^0 - \sigma\gamma y^0) \tag{14}$$

Multiplying both sides of (14) by $(1-\sigma)$ and replacing y^0 and w^0, the cartel is sustainable if:

$$\pi \leq \frac{(1-\sigma)(1-p)y}{[1-\delta(1-p)](\theta-1)} \tag{15}$$

The right-hand side of equation (15) is denoted by $\varphi(y)$. The present value of the collusive pay-off is denoted by:

$$y^0 = \int_{\underline{\pi}}^{\varphi(y)} \left\{\pi + \frac{\delta}{1-\delta}[(1-\sigma)y^0 + \sigma(w^0 - \gamma y^0)]\right\} g(\pi)d\pi + \int_{\varphi(y)}^{\overline{\pi}} \frac{\delta}{1-\delta}(w^0 - \sigma\gamma y^0)g(\pi)d\pi \tag{16}$$

The first integral represents the expected pay-off when the cartel is sustainable, i.e., the sum of probabilities that $\varphi(y)$ is higher than the expected pay-off when the agreement is respected, considering the profit lower bound $\underline{\pi}$. The second integral represents the expected pay-off when the cartel is not sustainable, i.e., the sum of probabilities of the expected pay-off of deviate when the sustainability condition is not satisfied, considering the upper bound $\overline{\pi}$ (all firms have incentives to deviate, therefore this is not a unilateral deviation). Multiplying both sides of (16) and replacing y^0 and w^0 we have:

$$y = \int_{\underline{\pi}}^{\varphi(y)} \left\{(1-\sigma)\pi + y[\delta - \frac{\delta\sigma(1-p)(1-\delta}{(1-\delta)(1-p)}]\right\} g(\pi)d\pi + \int_{\varphi(y)}^{\overline{\pi}} \frac{\delta p y}{(1-\delta)(1-p)} g(\pi)d\pi - \delta\sigma\gamma y \quad (17)$$

The right-hand side of (17) is denoted by $\psi(y)$. Then, Harrington and Chang (2009) and Zhou (2016) talk about the fixed-point theorem. According to the Brouwer fixed-point theorem, if $\mathbb{S}$ is a closed, limited and convex set and $f(x)$ a continuous function $f: \mathbb{S} \rightarrow \mathbb{S}$, there is a fixed-point $x^* \in S$ such that $f(x^*) = x^*$. In this case, a fixed-point of $\psi(y)$ is an equilibrium of $\psi(y)$. Given a value of y representing the collusion, the equilibrium of $\psi(y)$ is the same value of y. Let y^* be the maximum fixed-point of $\psi(y)$, such that $y^* = \max\{0 \leq y \leq \mu \mid \psi(y) = y\}$. A cartel is sustainable only if $y^* > 0$. The joint probability that a cartel survives to market fluctuations and to antitrust detection is $q(\sigma, \theta) = G(\varphi(y^*))(1-\sigma)$, i.e., in any period the cartel survives in accordance to the probability related to the function that guarantees the cartel sustainability $\varphi(y^*)$ and also according to the probability of no detection. The term $q(\sigma, \theta)$ can be denoted as the steady-state probability for a cartel to survive.

Now, we need to expand these concepts to industries. The term $s(t; \sigma, \theta)$ denotes the share of cartels (remember that the whole industry is cartelized or not) in the steady-state, cartelized for t periods in the industry type θ under the antitrust policy σ. The industry type θ is not cartelized when $t = 0$. The term $1 - \sum_{t=0}^{t-1} s(\hat{t}; \sigma, \theta)$ is the share of cartels that survive at least for t periods. The understanding of these formulas is possible looking at Harrington and Chang (2009). The first definition is the following:

$$s(0; \sigma, \theta) = s(0; \sigma, \theta)[(1-p) + p(\,1 - q(\sigma, \theta)) + p\sigma q(\sigma, \theta)] + [1 - s(0; \sigma, \theta)][\big(1 - q(\sigma, \theta)\big) + \sigma q(\sigma, \theta)] \quad (18)$$

The sum first term is related to the industries that start the period non-cartelized. A fraction $(1-p)$ has no opportunity to collude, a fraction $p(\,1 - q(\sigma, \theta))$ has the opportunity but choose not to collude due the cartel unsustainability, and the fraction $p\sigma q(\sigma, \theta)$ realizes the cartel but are detected later. The second term represents the industries that formed the collusion in the previous period. A fraction $1 - q(\sigma, \theta)$ is undone in the current period due internal reasons, while a fraction $\sigma q(\sigma, \theta)$ is detected by the antitrust authority. Solving for $s(0; \sigma, \theta)$ we have:

$$s(0;\sigma,\theta) = \frac{1-q(\sigma,\theta)}{1-(1-p)q(\sigma,\theta)} \tag{19}$$

Equation (19) represents the steady-state in which industries do not collude. The second definition is related to the share of industries that cartelize for t periods:

$$s(t;\sigma,\theta) = s(0;\sigma,\theta)pq(\sigma,\theta)^t \quad , t \geq 1 \tag{20}$$

In (20), the share $s(0;\sigma,\theta)p$ contains the non-cartelized industries that have the probability p of colluding. At the same time, a fraction $q(\sigma,\theta)^t$ will keep colluding for t periods after. Replacing (19) in (20) we have:

$$s(t;\sigma,\theta) = \frac{p[1-q(\sigma,\theta)]q(\sigma,\theta)^t}{1-(1-p)q(\sigma,\theta)} \quad , t \geq 1 \tag{21}$$

This is the share of cartelized industries that survive for t periods. At the same time, the share of cartels that survive for at least t periods is:

$$1 - \sum_{t=0}^{t-1} s(\hat{t};\sigma,\theta) = \frac{pq(\sigma,\theta)^t}{1-(1-p)q(\sigma,\theta)} \tag{22}$$

Now, it is possible to define the steady-state of the hazard of dissolution of discovered cartels in industries type θ under the antitrust policy σ_1:

$$h(t;\sigma_1,\theta) = \frac{s(t;\sigma_1,\theta)}{1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta)} = 1 - q(\sigma_1,\theta)\ , t \in \{1,2,\dots\} \tag{23}$$

Equation (23) means that the hazard of dissolution of discovered cartels in the steady-state is the ratio between the share of cartels that lasts until t and the share of cartels that survives at least for t periods. Denoting the share of industries capable of sustaining the cartel under the antitrust policies σ_1 and σ_2 by Θ_1 and Θ_2, respectively, the average steady-state dissolution hazard of discovered cartels (for all industries given an antitrust policy) is defined by the following:

$$\tilde{h}(t;\sigma_1) = \frac{\int_{\Theta_1} s(t;\sigma_1,\theta) f(\theta) d\theta}{1-\int_{\Theta_1} \sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta) f(\theta) d\theta} \quad (24)$$

Equation (24) can be expressed by:

$$\tilde{h}(t;\sigma_1) = \int_{\Theta_1} [\frac{s(t;\sigma_1,\theta)}{1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta)} \times \frac{1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta) f(\theta)}{\int_{\Theta_1}(1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta)) f(\theta) d\theta}] d\theta \quad (25)$$

$$\tilde{h}(t;\sigma_1) = \int_{\Theta_1} [h(t;\sigma_1,\theta) \times \frac{1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta) f(\theta)}{\int_{\Theta_1}(1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta)) f(\theta) d\theta}] d\theta \quad (26)$$

Therefore, $\tilde{h}(t;\sigma_1)$ is a weighted average of $h(t;\sigma_1,\theta)$, in which the weight is the probability of a cartel with duration of at least t periods being type θ. If there is an antitrust policy innovation, such that σ_1 increases to σ_2, a subset of Θ_1 will no longer be able to sustain the collusive agreement. The distribution of cartels represented by the second term of the multiplication in (26) will become:

$$\frac{1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta) f(\theta)}{\int_{\Theta_2}(1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta)) f(\theta) d\theta} \quad (27)$$

Nevertheless, the other cartels durations remain unaltered in the short-run. Thus, the average hazard of dissolution of cartels in the short-run is:

$$\tilde{h}(t;\sigma_1,\sigma_2,) = \int_{\Theta_2} [h(t;\sigma_1,\theta) \times \frac{1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta) f(\theta)}{\int_{\Theta_2}(1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta)) f(\theta) d\theta}] d\theta \quad (28)$$

The transition to a new steady-state requires the adjustment of the surviving cartels in each industry. The hazard of dissolution of discovered cartels changes from $h(t;\sigma_1,\theta)$ to $h(t;\sigma_2,\theta)$. Mathematically, the average hazard dissolution of cartels in the new steady-state becomes:

$$\tilde{h}(t;\sigma_2,) = \int_{\Theta_2} [h(t;\sigma_2,\theta) \times \frac{1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_2,\theta) f(\theta)}{\int_{\Theta_2}(1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_2,\theta)) f(\theta) d\theta}] d\theta \quad (29)$$

Based on the framework above, Zhou (2016) defines two propositions:

Proposition 1: If $\sigma_1 < \sigma_2$, $\tilde{h}(t;\sigma_1) \geq \tilde{h}(t;\sigma_1,\sigma_2)$ for all $t \in \{1,2,\dots\}$. It means that an increase in the rate of detection decreases the average hazard of discovered cartels.

Proposition 2: If $\sigma_1 < \sigma_2$, $\tilde{h}(t;\sigma_1,\sigma_2) \leq \tilde{h}(t;\sigma_2)$ for all $t \in \{1,2,\dots\}$. That is, after the immediate fall in the average hazard of discovered cartels following an increase in the detection rate, the hazard readjusts above the short-run levels.

The empirical analogue of *Proposition 1* is that an increase in the average duration of detected cartels right after the leniency program adoption corresponds to an increase of detecting capacities. It occurs because "marginal cartels" that are about to collapse (these cartels are indifferent between collude or not) would not form *ex-ante*, resulting that the discovered ones are longer-lasting cartels. The empirical analogue of *Proposition 2* is the following: after the initial increase of average durations, the readjustment below short-run levels corresponds to improved detection. This is because the formerly stable, long-lasting cartels will dissolve faster, which leads to a decline in observed average durations.

Now, we focus our attention of the Propositions proofs.

Proof of Proposition 1

Zhou (2016) defines two Lemmas to support the Propositions:

Lemma 1: In steady-state, the hazard of dissolution in an industry is increasing in relation to the deviation profitability and to the rate of detection. Thus, $\frac{dh(t;\sigma,\theta)}{d\theta} \geq 0$ and $\frac{dh(t;\sigma,\theta)}{d\sigma} \geq 0$ for all $\theta \in [\underline{\theta}, \overline{\theta}]$, for all $\sigma \in (0,1)$ and for all $t \in \{1,2,\dots\}$.

Lemma 2: If σ is sufficiently small, there exists $\tilde{\theta}(\sigma) \in [\underline{\theta}, \overline{\theta}]$ such that $y^* \leq 0$ when $\theta \geq \tilde{\theta}(\sigma)$ and $y^* > 0$ when $\theta < \tilde{\theta}(\sigma)$. That is, for a probability of detection sufficiently small, there is an inferior threshold that determines if the cartel is sustainable. At the same time, there is an upper threshold for which the cartel is not sustainable. In addition, $\tilde{\theta}(\sigma)$ is decreasing in σ.

Denote the second terms of the multiplications in (26) and (28) as:

$$p(\sigma_1,\theta) = \frac{1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta) f(\theta)}{\int_{\Theta_1}(1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta)) f(\theta) d\theta} \quad (30)$$

$$p(\sigma_1,\sigma_2,\theta) = \frac{1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta) f(\theta)}{\int_{\Theta_2}(1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta)) f(\theta) d\theta} \quad (31)$$

Equation (30) represents the distribution of the cartelized industries in steady-state under the antitrust policy σ_1, while Equation (31) is the distribution of the cartelized industries in the short-run right after the policy change. Replacing (30) and (31) in (26), separating the integrals and manipulating algebraically, the average hazard of cartel dissolution under σ_1 can be expressed by:

$$\tilde{h}(t,\sigma_1) = \int_{\Theta_2} p(\sigma_1,\theta)\ h(t;\sigma_1,\theta) d\theta + \int_{\Theta_1/\Theta_2} p(\sigma_1,\theta)\ h(t;\sigma_1,\theta) d\theta = \frac{p(\sigma_1,\theta)}{p(\sigma_1,\sigma_2,\theta)} \times \int_{\Theta_2} p(\sigma_1,\sigma_2,\theta)\ h(t;\sigma_1,\theta) d\theta + \frac{p(\sigma_1,\sigma_2,\theta) - p(\sigma_1,\theta)}{p(\sigma_1,\sigma_2,\theta)} \times \int_{\Theta_1/\Theta_2} \frac{p(\sigma_1,\theta) p(\sigma_1,\sigma_2,\theta)}{p(\sigma_1,\sigma_2,\theta) - p(\sigma_1,\theta)}\ h(t;\sigma_1,\theta) d \quad (32)$$

In which $\frac{\Theta_1}{\Theta_2} = [\tilde{\theta}(\sigma_2), \tilde{\theta}(\sigma_1)]$. Considering the average hazard of dissolution on the transition (Equation (28)) we have the following:

$$\tilde{h}(t,\sigma_1) - \tilde{h}(t;\sigma_1,\sigma_2) = \left(1 - \frac{p(\sigma_1,\theta)}{p(\sigma_1,\sigma_2,\theta)}\right) \times \int_{\frac{\Theta_1}{\Theta_2}} \frac{p(\sigma_1,\theta) p(\sigma_1,\sigma_2,\theta)}{p(\sigma_1,\sigma_2,\theta) - p(\sigma_1,\theta)}\ h(t;\sigma_1,\theta) d\theta - \int_{\Theta_2} p(\sigma_1,\sigma_2,\theta)\ h(t;\sigma_1,\theta) d\theta \quad (33)$$

Since $\sigma_1 < \sigma_2$, we have by Lemma 2 that $\tilde{\theta}(\sigma_2) \geq \tilde{\theta}(\sigma_1)$, thus $\Theta_2 \subseteq \Theta_1$. It informs that when the rate of detection increases the set of cartels able to sustain the collusion is reduced. Therefore:

$$\int_{\Theta_1}(1 - \sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta))\, f(\theta) d\theta \geq \int_{\Theta_2}(1 - \sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta))\, f(\theta) d\theta \quad (34)$$

An increase in the rate of detection results in $p(\sigma_1, \sigma_2, \theta) \geq p(\sigma_1, \theta)$, as can be observed from the denominators in (30) and (31), and by consequence $\left(1 - \frac{p(\sigma_1,\theta)}{p(\sigma_1,\sigma_2,\theta)}\right) \geq 0$. Replacing (30) and (31) in (33) and manipulating we have:

$$\tilde{h}(t, \sigma_1) - \tilde{h}(t; \sigma_1, \sigma_2) = \left(1 - \frac{p(\sigma_1,\theta)}{p(\sigma_1,\sigma_2,\theta)}\right) \times \int_{\frac{\Theta_1}{\Theta_2}} \frac{1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta) f(\theta)}{\int_{\frac{\Theta_1}{\Theta_2}} (1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta)) f(\theta) d\theta} h(t; \sigma_1, \theta) d\theta - \int_{\Theta_2} \frac{1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta) f(\theta)}{\int_{\Theta_2} (1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta)) f(\theta) d\theta} h(t; \sigma_1, \theta) d\theta \quad (35)$$

We have by Lemma 2 that $\Theta_1 = [\underline{\theta}, \tilde{\theta}(\sigma_1)]$, i.e., it is the set of cartels in which $y^* > 0$ under the policy σ_1. In the same way, $\Theta_2 = [\underline{\theta}, \tilde{\theta}(\sigma_2)]$. $\Theta_2 \subseteq \Theta_1$ if and only if $\sigma_1 < \sigma_2$. Thus, it is possible to conclude that $\theta_a \geq \theta_b$ for all $\theta_a \in [\tilde{\theta}(\sigma_2), \tilde{\theta}(\sigma_1)]$ and for all $\theta_b \in [\underline{\theta}, \tilde{\theta}(\sigma_1)]$. Therefore, $h(t; \sigma, \theta_a) \geq h(t; \sigma, \theta_b)$ for all $\theta_a \in [\tilde{\theta}(\sigma_2), \tilde{\theta}(\sigma_1)]$ and for all $\theta_b \in [\underline{\theta}, \tilde{\theta}(\sigma_1)]$. Intuitively, the hazard of cartel dissolution in the industry θ_a is higher than in θ_b if θ_a lies in the interval between the new and former antitrust policy ($\tilde{\theta}(\sigma_2)$ and $\tilde{\theta}(\sigma_1)$), while the parameter θ_b lies in the interval between the minimum value of θ and the parameter $\tilde{\theta}(\sigma_2)$ of the new policy. Thus:

$$\int_{\frac{\Theta_1}{\Theta_2}} \frac{1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta) f(\theta)}{\int_{\frac{\Theta_1}{\Theta_2}} (1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta)) f(\theta) d\theta} h(t; \sigma_1, \theta) d\theta \geq \int_{\Theta_2} \frac{1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta) f(\theta)}{\int_{\Theta_2} (1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_1,\theta)) f(\theta) d\theta} h(t; \sigma_1, \theta) d\theta \quad (36)$$

To conclude, if $\sigma_1 < \sigma_2$, $\tilde{h}(t, \sigma_1) \geq \tilde{h}(t; \sigma_1, \sigma_2)$ for all $t \in \{1, 2, \ldots\}$.□

Proof of Proposition 2:

It is the similar as Proposition 1. Define the following:

$$p(\sigma_2, \theta) = \frac{1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_2,\theta) f(\theta)}{\int_{\Theta_2} (1-\sum_{t=0}^{t-1} s(\hat{t};\sigma_2,\theta)) f(\theta) d\theta} \quad (37)$$

Replacing (37) in (29), separating the integrals and manipulating algebraically, the average hazard of dissolution of cartels under the policy σ_2 can be expressed by:

$$\tilde{h}(t,\sigma_2) = \int_{\Theta_2}\{h(t;\sigma_2,\theta) \times \int_{\Theta_2}[p(\sigma_2,\theta)]d\theta\}d\theta - \int_{\Theta_2}\left\{\frac{dh(t;\sigma_2,\theta)}{d\theta} \times \int_{\Theta_2}[p(\sigma_2,\theta)]d\theta\right\}d\theta = \int_{\Theta_2} h(t;\sigma_2,\theta)d\theta - [h\left(t;\sigma_2,\tilde{\theta}(\sigma_2)\right) - h\left(t;\sigma_2,\underline{\theta}\right) \quad (38)$$

Following the same procedures as in Proposition 1, $\tilde{h}(t,\sigma_1,\sigma_2) = \int_{\Theta_2} h(t;\sigma_1,\theta)d\theta - [h\left(t;\sigma_1,\tilde{\theta}(\sigma_2)\right) - h\left(t;\sigma_1,\underline{\theta}\right)$. According to Lemma 1, $\sigma_1 < \sigma_2$ implies that $h(t,\sigma_1,\theta) \leq h(t,\sigma_2,\theta)$ for all $\theta \in \Theta_1$. As $\Theta_2 \subseteq \Theta_1$, as previously exposed, we have that $h(t,\sigma_1,\theta) \leq h(t,\sigma_2,\theta)$ for all $\theta \in \Theta_2$. Therefore, $\tilde{h}(t,\sigma_2) \geq \tilde{h}(t;\sigma_1,\sigma_2)$. □

CONCLUDING REMARKS

This thesis presented three essays on antitrust economics and competition policy. Two of them focus on the Brazilian Leniency Program, a recent and valuable tool to fight cartels. The other paper is related to antitrust enforcement in a broader sense.

The first essay is about the interplay between the private and public antitrust enforcement in Brazil, an important debate currently. We concluded that it is optimal to grant immunity to the leniency applicant, as well as increase as much as possible the antitrust enforcement for damage claims. We provided three extensions that confirmed the following: the immunity is even more effective when there is risk of betrayal; the immunity is the best policy in the case of *ex-post* leniency; the immunity is the optimal policy when there is no bankruptcy, otherwise the applicant liability should be the minimum necessary to avoid the bankruptcy and to guarantee the refund to plaintiffs.

As highlighted within the paper, damage claims are set in the civil justice, thus out of the CADE scope. We propose an antitrust policy that interconnect the civil justice and antitrust laws. The proposed policy would specify the immunity to the leniency applicant following the guidelines above, while the civil justice would respect and follow the rule. This is a feasible policy, since when the Brazilian Antitrust Law provides criminal immunity for individuals it interconnects two justice areas, the criminal one and the antitrust law. After this policy implementation we suggest that CADE incentives as much as possible the damage claims for deter and destabilize cartels.

The second paper aimed to verify the antitrust enforcement impact on collusive industries with different degrees of product differentiation. The idea was to check if this enforcement is more effective when products are more homogeneous or differentiated. Based on a standard Bertrand duopoly, in which the cartel profit depends on the "collusive price", we concluded that the antitrust enforcement is more effective in constraining the "collusive price" when products are more homogeneous, although the total deterrence of all cartels occurs at the same point.

The results inform how a general antitrust enforcement impacts distinct industries, i.e., the antitrust parameters are the same for all industries. It is possible to define different parameters depending on the type of industry. For example, the antitrust authority could establish a public fight against cartels in procurements, or in gas stations, or in commodities, or any other type of agreement, resulting in a higher rate of detection and

possibly higher penalties in specific sectors. Our paper concludes that tougher antitrust policies are necessary to impact industries highly differentiated regarding products. The ideal scenario would be parameters so high that all cartels would be avoided.

Lastly, the third essay was an empirical evaluation of the Brazilian Leniency Program effectiveness. The main result was that the Brazilian Leniency Program is effective in increasing the hazard of dissolution of cartels in the long-run, which is consistent to the criterium of effectiveness provided by the theoretical and empirical frameworks.

Leniency Programs are considered one of the best tools for fighting cartels. We confirmed that this is an effective policy also for Brazil, an emergent country with some characteristics that could affect its effectiveness, such as the economic environment and the antitrust laws. Despite favorable results, CADE should keep looking at some ways to increase the Brazilian Leniency Program effectiveness, especially regarding the damage liability for the leniency applicant, the length of investigation, among other aspects. These issues could contribute even more to increase the hazard of dissolution of cartels in the long-run.

Antitrust issues represent an important field of study in Law and Economics and Industrial Organization, especially for economists and policy makers. Despite the importance of other topics (as mergers and abuse of dominant position), antitrust authorities devote a great amount of time, money and resources on the fight against cartels. It is well known that collusive agreements seriously harm consumers and the economy in general, that is why fighting them is a priority for many countries.

It is worth noting that cartels can take many forms, besides adapt themselves for fooling new policies. An example is when gas stations combine rotative prices (or other type of agreement) instead of similar prices to avoid statistics filters. The same can occur with participants in a procurement. Another example is the "*hub and spoke cartel*", occurring when the members use one or more common suppliers to communicate, avoiding criminal proofs. Therefore, cartel members are always trying not to create suspicious and proofs on the infringement, requiring that antitrust authorities should be always active in developing new tools to fight cartels, as well as understanding the impact and consequences of these tools.

The academic literature on antitrust issues and competition policy is essential in this context. Our intention with this thesis is providing useful and relevant information about antitrust policies in Brazil and abroad. We believe that our results are policy

relevant, in the sense that the conclusions derived in each paper could help to guide the antitrust authority action.

Much studies need to be done in the future. Little is known about antitrust and cartels from an economic viewpoint in Brazil, thus there are several topics for suggestion. First, the theoretical models of the first two papers are static, meaning that firms cannot adapt them decisions according to past choices. It is possible to analyze these questions with dynamic models of game theory, for example using the Markov Perfect Equilibrium criterium. Obviously, dynamic models would also allow for new parameters, interpretations and research problems. Second, it is important to evaluate the Brazilian Leniency Program effectiveness in other ways, for example analyzing how this policy changed the number of cartels discovered. Lastly, as the current antitrust law in Brazil is the Law nº 12.529/2011, probably this one was a milestone for competition policy in the country. The impact of this Law on the cartel behavior must be analyzed in the future in severals ways, for instance as a structural break, as changing the Leniency Program rules, as defining new penalties, and so on.