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Damage actions may reduce the attractiveness of leniency programs for cartel participants if their cooperation with the competition authority increases the chance that the cartel's victims will sue them. This apparent conflict between public and private antitrust enforcement has led to calls for a legal compromise. Our analysis shows that the conflict is only due to poor legislation and that a compromise is not required: limiting the cartel victims' ability to recover their loss is not necessary to preserve the effectiveness of a leniency program and may be counterproductive. We show that damage actions will actually improve its effectiveness, through a legal regime in which the civil liability of the immunity recipient is minimized and full access to all evidence collected by the competition authority, is granted to claimants. Our results help compare the EU and US damage systems and directly question the 2014 EU Directive which tries to protect the effectiveness of a leniency program by preventing the use of leniency statements in subsequent actions for damages.

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1 Introduction

Anti-cartel enforcement is central to antitrust and is its crucial component in terms of effects on a country's productivity growth (Buccirossi et al. (2013)). Cartels, however, remain a widespread phenomenon with serious consequences to society and welfare.[1] Optimizing anti-cartel enforcement is therefore an important public policy issue.

Public and private competition law enforcement have complementary objectives and, in general, tend to reinforce each other. However, a conflict between them may arise in the fight against cartels. This conflict may be due to the central role played by leniency programs (LPs) in cartel probes. LPs provide a fine reduction (up to immunity) to cartel members in exchange for reporting the cartel and further cooperation with an investigation.

Private action for damages may jeopardize LPs since a leniency application increases the risk of a successful damage action by the cartel's victims. First, the evidence provided by the leniency applicant may be used by the claimants to prove the existence of the infringement and its effects. Second, leniency applicants, and especially immunity recipients, normally do not challenge in court the infringement decision adopted by the competition authority (CA), at least as far as the existence of the cartel is concerned. Since the cartelists are joint and severally liable towards all the cartel's victims, the leniency applicant may become the preferred target of the damage action for the entire harm caused by the cartel. Hence, the incentive stemming from the avoidance of a fine may be counterbalanced by the increased risk of being condemned to pay damages.

Two issues are particularly important in finding the right balance between public enforcement and the protection of the LP on one side, and private enforcement and the protection of the victims' right to compensation on the other. The first issue is whether leniency applicants (and in particular, the immunity recipient) should have the same

[1] See Levenstein and Suslow (2006) and Marshall and Marx (2012), among others.

level and type of liability as all other cartelists. The second issue is whether access to the leniency statements and related documents should be granted to the claimants in the damage action.

These two issues have been addressed differently in various jurisdictions. In the US, victims of an antitrust infringement are entitled to treble damages and cartel members are jointly and severally liable for these damages. Moreover, the applicable discovery rules allow claimants in a damage action to obtain full disclosure of all relevant documents, including those provided by the leniency applicants.[2] In order to reduce the risk of the effectiveness of the US LPs being undermined, the US Congress enacted the Antitrust Criminal Penalty Enhancement and Reform Act (ACPERA) in 2004. ACPERA eliminates treble damages and joint liability for the amnesty recipient, who also has a duty to cooperate with the claimants in the civil action. Hence, the cooperating party is only exposed to single damages (detrebling), while the other conspirators will cover the additional damages. ACPERA did not change the rules concerning the disclosure of relevant documents so that claimants can still rely on the evidence provided by the leniency applicants.

The recent EU Directive (European Commission (2014)) disciplines the matter in the EU.[3] With regards to liability, the Directive provides "*that an immunity recipient is jointly and severally liable as follows: (a) to its direct or indirect purchasers or providers; and (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*" (Art. 11(4)).

With regards to access to documents submitted by a leniency applicant (not only the immunity recipient), the Directive provides that "*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.*" (Art. 6(6)). Moreover, article

[2]Note that, while judges do not request the leniency documents from the Department of Justice (DOJ), they can subpoena the firms and obtain all of the evidence a firm provided the DOJ with.

[3]The Directive is still to be transposed in the national legislations.

7(1) provides that *"Member States shall ensure that evidence in the categories listed in Article 6(6) which is obtained by a natural or legal person solely through access to the file of a competition authority is either deemed to be inadmissible in actions for damages or is otherwise protected under the applicable national rules*".

A rather interesting measure was adopted in Hungary in 2009[4], pre-directive, where the immunity applicant can be called on to compensate the cartel's victims if and only if the other cartel members are unable to pay the damages awarded to the claimants. The protection granted to the immunity recipient does not prevent the access to the information and evidence provided to the competition authority.

For simplicity, in the following we will refer to the three legal regimes described above as the US, the EU and the Hungarian solutions.

In this paper we theoretically analyze the interaction between these rules and the effectiveness of leniency programs in terms of the effects on general deterrence. Our theoretical analysis also allows us to examine whether the US, EU, and Hungarian solutions are appropriate, taking into consideration both the objective of preserving (or improving) the effectiveness of the LP and the objective of guaranteeing the right to compensation of the cartel's victims. We investigate whether pursuing the primary goal of the public enforcement system, i.e. achieving an optimal level of deterrence of anticompetitive conducts, necessarily requires sacrificing the amount of damages that claimants can expect to recover, or whether, these two objectives can both be pursued in a consistent and complementary way, and if so to what extent and how. We focus on leniency awarded to parties that spontaneously report the cartel when the CA is unaware of its existence, since this type of leniency has unambiguously positive effects on deterrence, as long as sanctions are robust.[5]

In Spagnolo (2004), it is shown that, in order to maximize deterrence in the presence of a leniency program, it is optimal to minimize the amount of damages paid by

[4] Art.88D of the Hungarian Competition Act (1996), revised in 2009.

[5] On the contrary, leniency awarded when the CA is already aware of the cartel's existence has ambiguous effects (see Motta and Polo (2003)).

the first (and only the first) reporting firm. However, how much information from the leniency report has to be disclosed in the civil action and the right of victims to be compensated were not taken into account. Here, we extend Spagnolo (2004) to include these two additional elements. We determine the optimal combination of damage liability of the reporting firm and the amount of information which should be accessible to the claimants (which includes leniency statements), both in terms of deterrence and of the ability of victims to be compensated.

We find that, normally, there is no conflict between the two objectives, contrary to what is presumed in the legal debate. To maximize the attractiveness of the leniency program and deterrence, it is optimal to a) minimize the amount of damages the leniency applicant is liable for, and b) maximize the share of information collected by the competition authority and made accessible to the claimants, including leniency statements. Hence, we suggest a legal regime in which the immunity recipient's liability is reduced as much as possible (and possibly eliminated) and full access to the leniency statements is granted to the claimants in the ensuing damage actions. In the following this regime is referred to as "our proposal".

When we examine expected damages to be awarded, we find that as long as competitors are able to jointly cover the damages caused by the leniency applicant, our proposal is also optimal, as it maximizes the possibility for victims to obtain compensation for harm. In the EU, claimants are worse-off under the new Directive in comparison with both the previous legal system and the legal system that would result from our proposal. The latter dominates both the other systems and maximizes deterrence. The US solution is also suboptimal. It can be improved by granting the amnesty recipient full immunity on civil liability. The Hungarian solution instead works well since, if there is no risk of bankruptcy, it is in fact equivalent to our proposal.

We also examine strategic risk (the fear of being betrayed by a partner applying for leniency) as a deterrence channel, and extend the model to include the cost of being the

preferred target of the damage actions. We find that both these factors further increase the efficiency gain of our proposal.

Finally, we consider the case in which cartel members' assets suffice to pay awarded damages only if the first leniency applicant is not kept immune from its civil liability. In this situation a possible conflict between deterrence and victims' rights for compensation may emerge. We show that, in this scenario, the Hungarian solution can be considered a "second best" which maximizes deterrence under the constraint of holding the value of expected liquidated damages constant.

In our analysis we emphasize that the right to compensation of the potential victims of cartels that are deterred should be more explicitly taken into account than what was done in the current debate. Then it becomes clear that deterrence, the effectiveness of public enforcement, must "matter more" than the right of actual victims to obtain compensation. Deterrence prevents the allocative inefficiency brought about by cartels, and at the same time it also ensures that the potential victims of the deterred cartels obtain "full compensation", as that harm is directly prevented. If we think that distributive considerations are irrelevant and only efficiency should matter, then there would be no reason for granting a right to be compensated to the victims of actual cartels, unless this right positively contributed to the efficiency goal through deterrence. As a consequence, the right to be compensated should always be limited whenever it reduces the deterrence properties of the enforcement system. If instead we think that distributive considerations are also important, then we have to place the same weight on the welfare of the actual victims of undeterred and detected cartels and of customers of potential cartels that do not form because of increased deterrence. In both cases, deterrence considerations and the right of actual victims to obtain compensation cannot be given the same status, as sometimes done in the current debate. We see clarifying this as an important contribution of our paper. Indeed, if we take into account the interest of all actual and potential victims, then our proposal (i.e. full protection from liability for the

leniency applicant) is likely to perform even better than the Hungarian solution.

The remainder of the paper is organized as follows. *Section 2* relates this paper to the relevant economic and legal literature. *Section 3* presents the theoretical model. *Section 4* discusses some extensions of the basic model: 1) deterrence linked to strategic risk; 2) the impact of being the preferred target in damage actions; and 3) the risk of bankruptcy. *Section 5* concludes. All proofs and derivations are in the Appendix.

2 Literature review

The possible conflict between public and private enforcement has originated a long and ongoing debate. In the EU, this culminated with the recently approved Directive.[6] In this section, we review this legal debate and then the economic literature on the trade-off between public and private enforcement.

2.1 The recent legal debate

Before the adoption of the Directive, the issues of liability of the immunity applicant and access to leniency statements, were dealt with by applying some general legal principles.

The first relevant principle, as stated by the European Court of Justice (ECJ) in the *Manfredi* (2006)[7] and *Courage* (2001)[8] judgements, is that the victims of an antitrust infringement have a right to be fully compensated for the harm they suffered. If a more favorable treatment of a leniency applicant with respect to its civil liability hindered the effective exercise of this right to a full compensation, it would run against this principle. As for the access to the leniency statements, in a judgement concerning a referral from

[6] For a complete survey on private and public enforcement of antitrust law see Segal and Whinston (2006).

[7] Judgement of the Court of Justice of 13 Jul. 2006, Joined Cases C-295/04 to C-298/04, Manfredi, ECR I-6619.

[8] Judgement of the Court of Justice of 20 Sept. 2001, Case C-453/99, Courage, ECR I-6297.

the district court of Bonn in Germany (*Pfleiderer* case)[9] the ECJ ruled that EU law does not prohibit a third party, who has been adversely affected by a breach of competition law, from having access to a leniency application by the infringer. The court held that it is for the national judge to determine the conditions under which access to leniency material can be granted to someone seeking to obtain damages. According to the ECJ, the national judge would need to take into account and weigh all the interests protected by EU law, namely the need to ensure the effectiveness of leniency programs and to support antitrust damage actions.[10] This position has been confirmed in the more recent *Donau Chemie* judgement,[11] where the ECJ affirmed that national courts must balance these possibly conflicting interests on a case-by-case basis, taking into consideration all the relevant facts of the case.

The legal debate has been active regarding the coexistence of private and public enforcement (Shavell (1997), Lande and Davis (2011) and Bernard (2012)) and the interaction between leniency programs and damage claims.

More closely related to the question posed in this paper are the papers by Komninos (2011), Cauffman (2011) and MacCulloch and Wardhaugh (2012), which describe the relationship between leniency programs and damage claims. While Cauffman (2011) and MacCulloch and Wardhaugh (2012) suggest that the effectiveness of leniency should prevail and, therefore, the reports should not be disclosed, Komninos (2011) proposes a case-by-case approach. In addition, Komninos (2011) and Cauffman (2011) suggest that the reporting firm should have further limited liability. These proposals are somewhat in line with what has been approved in the new Directive. Two other papers examine the Directive itself. In line with the results of our formal analysis, Kortmann and Wesseling (2013) and Geradin and Grelier (2013) view the Directive as being flawed in the sense that the liability of immunity recipients should be further

[9] Judgement of 14 June 2011 in the case C-360/09.

[10] On 30 January 2012, the German court which had brought the case before the ECJ concluded that access to leniency documents should be denied.

[11] Case C-536/11 – *Bundeswettbewerbsbehörde v Donau Chemie AG and others*.

reduced.

2.2 Economic literature

Shavell (1997) was one of the first to explore the differences between the social and private incentives to litigate from a legal perspective. The author argues that achieving a number of litigations which is neither socially excessive nor socially inadequate requires corrective social policies and the guarantee that the claimants have more knowledge than the public regulators have or could possibly obtain. The author points out that low litigation costs allow more plaintiffs to access justice but encourages them to sue firms even in cases where the social costs exceed the social benefits and, according to Bourjade et al. (2009), where lawsuits are poorly founded. Bourjade et al. (2009) study, theoretically, the effect of encouraging private actions for breaches of EU competition law by developing a model of litigation and settlement with information asymmetry. The authors conclude that it is better to increase damages than to reduce the cost of suing.

McAfee et al. (2008) develop a theoretical model which compares private and public enforcement and find that, if the courts resolve with a low error level, then only legitimate suits are submitted and the optimal solution is the conjunction of public and private enforcement. This is because private parties have a better signal of the violation than the public agency. The authors assume that neither private nor public entities can commit and that public entities aim to maximize social welfare. In this scenario, they propose a system where private claimants pay a subsidy for public investigation in exchange for a monetary award following a conviction.

More directly relevant to this paper is Spagnolo (2004), showing that in order to maximize deterrence an optimal leniency program minimizes (eliminates) the liability for damages of the first spontaneously reporting firm (only), a proposal supported also by some practitioners (see e.g. Green and McCall (2009)). This paper is therefore also

related to the recent but extensive literature on the economics of leniency programs, starting with the contributions by Motta and Polo (2003), Spagnolo (2004), Aubert et al. (2006), Buccirossi and Spagnolo (2006), Harrington (2008), Harrington (2013), Chen and Rey (2013) and many others.[12]

3 A simple model

We try to develop the simplest possible model from which to rigorously derive our results. This is both because our results are very intuitive - although only a formal analysis allows to verify their robustness; and because we hope to reach the widest possible audience, including the legal and policy domains.

Consider an economy composed of a continuum of industries. In each industry, two symmetric firms produce a homogeneous good and repeatedly play a Bertrand game in the infinite, discrete time. Firms may choose to enter a collusive agreement to maintain a high price and escape the poor competitive outcome. If they do, and respect the agreement, each of them earns (at most) collusive profits Π per period.

In each industry, firms share the same discount factor δ. However, each industry has a different discount factor, for example because of different frequency of market interactions, and the different industry discount factors are uniformly distributed in the interval $(\frac{1}{2}, 1)$[13], so that collusion is sustainable in every industry.

We assume that to reach a collusive agreement firms need to communicate, that hard and compromising evidence is produced only after both firms agree to collude, and that this evidence, available to cartel members, can also be found by a CA that investigates the industry. If a cartel forms between the two symmetric firms, the likelihood that the CA investigates, finds evidence on the collusive agreement and successfully prosecutes the cartel members without any of them cooperating with the investigation (revealing

[12] Marvão and Spagnolo (2015) offer a review of the empirical and experimental evidence of the effectiveness of leniency programs.

[13] With $\delta < \frac{1}{2}$ collusion is not sustainable, independently of antitrust enforcement.

information) is ρ, with $0 < \rho < 1$. A leniency program (LP) is in place, encouraging cartel members to self-report such hard evidence before any such investigation.

If a cartel is convicted because of an independent investigation by the CA, each member must pay a fine F that, for simplicity, we assume is exogenously given, as in most previous analysis. If a cartel is convicted because one of the firms reported the hard information within the LP, the reporting firm pays no fines while the other pays the full fine F. If both parties self-report, each of them pays half of the fine.

In each period, the timing of the game is therefore as follows:

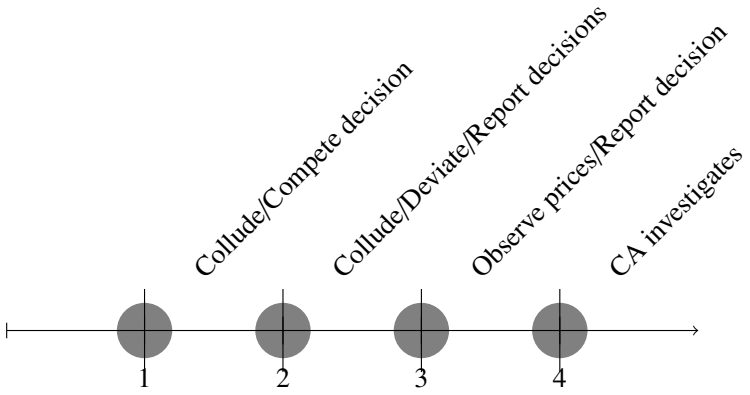
- Stage 1: Each firm chooses whether to enter into a collusive agreement. If at least one firm chooses not to collude, then competition "à la Bertrand" takes place and the game ends for that period. The competitive Nash equilibrium generates zero profits for both firms. Otherwise:

- Stage 2: Each of the firms chooses whether to respect the agreement and "collude", quoting the agreed upon price, or to deviate from it, undercutting the agreed upon price. Firms can also choose whether to apply to the LP and report the cartel to the CA. If at least one of the firms applies, the game ends for the period. Otherwise:

- Stage 3: Quoted prices become public information. Firms choose whether to apply for the LP and report the cartel to the CA. If at least one of the firms applies to the LP, the game ends for the period. Otherwise:

- Stage 4: The CA chooses which industries to investigate, ρ realizes, and the game ends for the period.

The figure below shows a graphical representation of the stage game.



3.1 Damages

In addition to fines, cartel members are liable for compensation of buyers. The maximum amount of estimated damages for each firm is D, so that the maximum amount of damages for which the cartel is liable is $2D$. The fraction of these maximum total damages that each convicted firm will have to pay, depends on the liability rules defined by the legislation in the various situations. The amount of damages that convicted firms expect to pay will also depend on the amount of information available to victims after the conviction, denoted by α, with $0 < \alpha < 1$.

We will start by analyzing the effects of different liability and disclosure rules on deterrence and on victims' expected compensation under the assumption that there is no risk of bankruptcy, in the sense that each firm is solvent for its own direct damages and non-reporting cartel members have sufficient assets to jointly cover the damages caused by the cartel, including those caused by the leniency applicant. While we believe this assumption captures the current situation well, particularly for large cartels, we will also discuss what happens if it is not satisfied. For simplicity, it is also assumed that firms do not appeal decisions.

We can denote the amount of damages a given firm is liable for by D^{NR} if no firm applies to the LP; by D^{R} if the firm applies to the LP but the other cartel member does not; D^{OR} if only the other cartel member applies and reports the cartel; and D^{BR} if both

do. In the US and in the EU solutions, we have that $0 < D^R \leq D^{NR}$. In the Hungarian solution $D^R = 0$ if there is no risk of bankruptcy by the non-reporting firm and $0 < D^R \leq D^{NR}$ otherwise.

The expected total damages that firms have to pay are a function of the amount of information available to victims, after a cartel is convicted, to use when suing for damages in each case. We denote the amount of this information by α^{NR} if no firm reports under the LP (or if the leniency statement cannot be disclosed), and α^R if at least one firm reports, with $\alpha^R \geq \alpha^{NR}$.

As mentioned in the introduction, the EU solution restricts disclosure of leniency statements, thereby setting $\alpha^R = \alpha^{NR}$. In the US and the Hungarian solutions $\alpha^R \geq \alpha^{NR}$ as the applicable rules do not affect the claimants' ability to use the evidence provided by the leniency applicants in the damages actions. Our proposal is instead to do the opposite, that is, set $D^R = 0$ and maximize α^R.

3.2 Analysis

To sustain collusion, agents use a grim-trigger strategy, which is reversion to a permanent competitive Nash equilibrium, in case of deviation. The environment is stationary, so if no deviation is observed, firms continue to collude after they are convicted by a random investigation by the CA.[14] A firm that deviates by undercutting price also finds it optimal to apply to the LP at the same stage (Stage 2). Firms can therefore sustain a stationary collusive agreement in a subgame perfect Nash equilibrium if the expected gains from respecting the collusive agreement and not reporting are larger than the expected discounted gains from optimally deviating and reporting under the LP.

If firms choose not to report, they will earn in each period, a net profit of Π minus the expected penalty ($F + \alpha^{NR}D$). However, if a firm deviates and simultaneously

[14]This is as in Chen and Rey (2013). The results would not change if we assumed that collusion would stop, temporarily or permanently, after a successful conviction of the cartel linked to a random investigation, without any deviation from the cartel partners.

reports, while the other firm complies, it will earn profits of 2Π and it will receive immunity from fines ($F = 0$), although it will still be liable for damages to the amount of $\alpha^R D^R$. The expected discount values of reporting (R) and not reporting (NR) are then:

$$V_{NR}(C, C) = \frac{\Pi - \rho(F + \alpha^{NR} D)}{1 - \delta}$$
$$V_R(R, C) = 2\Pi - 0 - \alpha^R D^R$$

The incentive compatibility constraint (ICC) below, determines the minimum discount factor $\underline{\delta}$ necessary for collusion to be sustainable in equilibrium:

$$V_{NR} - V_R > 0 \leftrightarrow \delta > \underline{\delta} \equiv 1 - \frac{\Pi - \rho(F + \alpha^{NR} D^{NR})}{2\Pi - \alpha^R D^R} \tag{1}$$

Since collusion is sustainable in equilibrium only in those industries where $\delta > \underline{\delta}$, an increase in $\underline{\delta}$ increases cartel deterrence, as it directly reduces the number of industries that satisfy the condition for collusion to be an equilibrium.

It can be easily seen that when $\alpha^R D^R$ decreases, $\underline{\delta}$ increases. Therefore, in the presence of a leniency program which provides the first applicant with immunity from fines, and with private enforcement in the form of damage claims, to maximize deterrence in terms of the number of industries in which no collusive equilibrium exists, $\alpha^R D^R$ should be set at its minimum level. Since α^R belongs in the interval $(\alpha^{NR}, 1)$, the minimal level of $\alpha^R D^R = 0$ can only be achieved by limiting leniency applicants' liability, setting $D^R = 0$ as we suggest.

By reducing the amount of information victims can access and use in private damage suits (in particular, leniency statements), setting $\alpha^R = \alpha^{NR}$, as is done in the EU solution, can never lead to maximal deterrence. Similarly, the legal regime determined in the US solution leads to a level of deterrence that is below the maximum that can be achieved through a more generous LP. The Hungarian solution, instead, is optimal

if there is no risk of bankruptcy as assumed in this basic version of the model, because D^R is effectively zero.

Proposition 1: *The effectiveness of the leniency program, in terms of deterrence, is strictly smaller under the EU solution or under the US solution than under our proposal and the Hungarian solution.*

The various policies are also not equivalent regarding the possibility of victims to obtain compensation for harm. In particular, we compare the EU solution and our proposal. In equilibrium, no cartel is formed that is subsequently reported. However, suppose that unexpected trembles in the discount factor of firms may occur. A sufficiently large tremble downwards would lead to a violation of the ICC, inducing that firm to deviate and apply for leniency. Under our policy, the amount of total damages expected by victims as compensation is $\alpha^R 2D$. Under the EU solution, since $\alpha^R = \alpha^{NR}$, it would be $\alpha^{NR}2D < \alpha^R 2D$.

An alternative way of looking at the effect of these policies on the right of compensation of victims (both aware and unaware) is to evaluate the amount of damages which is left uncompensated. Suppose there is an unexpected change in the legal regime, which creates a shift in the discount factor from $\underline{\delta}$ to $\underline{\delta'} > \underline{\delta}$. Assume this change implements our proposal, thus replacing the EU solution.

In industries where $\underline{\delta'} > \delta > \underline{\delta}$, the increase in $\underline{\delta}$ leads cartels to collapse, report and pay a fraction (α^R) of the damages. The total of uncompensated damages in these industries is given by $(\underline{\delta'} - \underline{\delta})(1 - \alpha^R)2D$, which is zero in our proposal. In the remaining industries, with $\delta > \underline{\delta'}$, cartels survive and the loss in damages is given by $(1 - \underline{\delta'})2D$. With the EU solution, the amount of uncompensated damages was $2D(1 - \underline{\delta})$. It follows that our proposal reduces the amount of uncompensated damages by $2D[\underline{\delta'} - \underline{\delta}]$. It is immediate to see that this result holds true also for the US solution.

Proposition 2: *The effectiveness of the leniency program, in terms of the ability of victims to obtain compensation and in terms of the loss in non-compensated cartel damages, is strictly smaller under the EU or US solutions than under our proposal.*

4 Extensions

In this section, we discuss how our previous results change when we take into account strategic risk, being the preferred of damage actions and the possibility of bankruptcy.

4.1 Strategic risk

It is natural that each firm considers the possibility of being betrayed by the other cartel member. A collusive agreement, to be viable, also requires that firms trust each other, i.e. that they have sufficient confidence that co-conspirators will respect the agreement and will not get "cold feet" and report the cartel so as to obtain a lenient treatment.

Leslie (2004) argued, from a legal point of view, that it is important to take into account distrust among cartel members, the fear of being reported by a co-conspirator, as a source of deterrence. Spagnolo (2004) formally showed that this fear constitutes an additional deterrence channel for collaborative crimes, by introducing the concept of strategic risk to capture it formally, and that - cœteris paribus - a well designed and run LP (i.e. "strict", as in limited to the first spontaneously reporting party, and with powerful incentives, e.g. high fines for non-reporting parties) can strongly increase cartel deterrence by increasing this fear.[15] Bigoni et al. (2015) provide experimental evidence on the power of this novel deterrence channel for collaborative crimes, show-

[15]The game theoretic foundations of this concept have been developed in Blonski et al. (2011) and Blonski and Spagnolo (2015). Additional experimental evidence of the importance of this type of strategic risk was found by Dal Bó and Fréchette (2011), Blonski et al. (2011) and Bigoni et al. (2014) and Breitmoser (2015).

ing that cartel formation falls dramatically when a (strict) LP is introduced, even when the probability that the cartel is independently detected by the CA when nobody reports under the LP, is zero.[16]

In this section, we take into account this novel deterrence channel and check whether and how the results of the previous section change in its light.

The simplest way to take into account the effect of strategic risk on an agent's choice regarding whether or not to form a cartel is to see it as an equilibrium selection criterion. When collusion satisfies the ICC, the game has multiple equilibria - collusive and competitive ones. Strategic risk points at equilibria that are less "risky", i.e. where the consequences of the opponent not playing the equilibrium strategy ("deviating") are less negative. It trades off equilibrium gains and losses if the opponent defects, and tells us which equilibrium is likely to be selected in different environments. The collusive equilibrium is more profitable than the competitive one, but it exposes the firm to the risk of being "cheated upon", a particularly costly event in the presence of a LP, as a deviating opponent will then also report the cartel to the CA. We can then derive a minimum level of the discount factor $\underline{\delta}^*$ necessary for the higher strategic risk of collusive equilibrium to be dominated by higher expected profits so that subjects choose to collude. The minimum discount factor necessary for firms to choose the collusive equilibrium rather than the reporting one will of course always be strictly larger than that necessary for a collusive equilibrium to exist in the first place, as defined by the ICC (i.e. $\underline{\delta*} > \underline{\delta}$).

To derive $\underline{\delta*}$, we use the best response equivalent matrix to calculate the "Nash products" of the two pure strategy equilibria, as shown in the Appendix. Collusion is

[16] A more recent experiment by Chowdhury and Wandschneider (2014) confirms the robustness of this result. For an overview of available empirical and experimental evidence on the effects of leniency programs, see Marvão and Spagnolo (2015).

risk dominated by reporting when:

$$\delta < \underline{\delta*} \equiv 1 - \frac{\Pi - \rho(F + \alpha^{NR} D^{NR})}{3\Pi + \frac{F}{2} + \alpha^{R}(D^{OR} - D^{BR} - D^{R})}$$

Given that it is always the case that $\underline{\delta*} > \underline{\delta}$, maximizing deterrence while taking into account strategic risk considerations amounts to maximizing $\underline{\delta*}$. The comparative statics of $\underline{\delta*}$, also derived in the Appendix, prove the following.

Lemma 1: Taking into account strategic risk (the fear of betrayal), cartel deterrence is:

a) decreasing in D^R;

b) increasing in D^{OR}; and

c) increasing in α^R if $D^R < \frac{D}{2}$ and decreasing in α^R if $D^R > \frac{D}{2}$.

Also taking strategic risk also account changes our previous conclusions in two ways. First, it highlights the fact that minimizing D^R is not only important for increasing the incentives to defect (Lemma 1a), but also because it automatically increases the liability of firms that do not report D^{OR} (Lemma 1b). This worsens the consequences and increases the fear that if you choose to collude, your partner may report you under the LP. Second, it shows that for full disclosure to maximize the effectiveness of cartel deterrence, the liability of the party reporting under the LP must be reduced more than it was suggested by the ICC in the previous section. The optimal policy in terms of the effectiveness of the LP, however, does not change, nor do the consequences for the ability of victims to claim damages. It can also be shown that the EU and the US solutions lead to a further loss of efficiency.[17] We can therefore state the following.

Proposition 3: *Taking into account strategic risk (the fear of being reported), the ef-*

[17] Proof in the Appendix 6.3.

fectiveness of the leniency program, in terms of cartel deterrence and the ability of the victims to obtain compensation when a cartel is reported, remains strictly smaller under the EU and the US solutions than under a policy that further reduces liability for the first firm that reports under the leniency program and maximizes information disclosure to victims, giving full access to leniency statements for private actions. Moreover, the efficiency loss implied by the EU and the US solutions is larger than that implied by the ICC and Proposition 1.

4.2 Preferred target

In the previous sections, the model does not take into account the incentives of lawyers to target a specific cartel member in the action for damages. Let T denote the cost of being the preferred target of the action for damages. If neither or both firms report, then this cost is equally divided between the cartel members ($\frac{T}{2}$).

When only one firm reports, in the EU solution (*scenario II*), both firms have the same probability of being the target of the damage action and each supports half of the cost ($\frac{T}{2}$). Before the recent Directive (*scenario I*), the reporter was the preferred target, supporting all the cost (T). In our solution (*scenario III*), the reporter has a lower liability for damages and the non-reporting cartel member supports the full cost (T).

Taking T into account, we calculate new expressions for the discount factors and we compute comparative statics on the discount factors in the three scenarios (proofs and derivations can be found in the Appendix). It can be shown that the difference between the discount factors of scenarios *III* and *II* is increasing in T . This means that the efficiency gain of the proposal over the EU solution is larger when T is taken into account:

$$\frac{\partial[\underline{\delta*}^{(III)}(T) - \underline{\delta*}^{(II)}(T)]}{\partial T} = \frac{(V'_{NR} - \rho T)(V_{BR} - V_{OR} + V_R)^2 + \frac{T^2}{4}V'_{NR}}{[(V_{BR} - V_{OR} + V_R)^2 - \frac{T^2}{4}]^2} > 0 \qquad (2)$$

Proposition 4: *Taking into account the cost of the claimant's choice of the preferred target of damage claims further increases the loss of deterrence implied by the EU solution (II) relative to the optimal policy (III).*

4.3 Bankruptcy

Another relevant extension of our model is to consider a setting where firms may go bankrupt. In this extension, we consider the simple case in which each firm individually has assets (W) that are insufficient to pay the fine and the awarded damages if the cartel is uncovered by the CA under its own initiative or if the cartel is uncovered because the other cartelist reported it to the CA. In this setting, a firm that does not cooperate with the CA goes bankrupt if the cartel is detected and is condemned to pay damages. However, we assume that if both firms are liable towards the victims, their total assets ($2W$) are sufficient to pay both the sanctions and damages. We further assume that if a firm goes bankrupt it is immediately replaced by another identical firm, so that the competitive conditions in the market do not change. We focus only on the incentive compatibility constraint.[18]

The analysis is straightforward. If firms do not report in each period, with probability $(1-\rho)$ each of them obtains Π and with probability ρ the cartel is caught by the CA and fails, so that its payoff is 0. Hence, the expected discounted value of not reporting is:

$$V_{NR}(C,C) = \frac{1-\rho}{1-(1-\rho)\delta}\Pi$$

The expected discounted value of reporting does not change with respect to the

[18] However, our conclusions remain valid if we take into account strategic risk considerations.

previous analysis, and is therefore:

$$V_R(R, C) = 2\Pi - \alpha^R D^R$$

The minimum discount factor for collusion to be sustainable becomes:

$$\underline{\delta} \equiv \frac{1}{1-\rho} - \frac{\Pi}{2\Pi - \alpha^R D^R}$$

and it is clearly decreasing in $\alpha^R D^R$, so that *Proposition 1* is unaffected.

However, *Proposition 2* does not necessarily hold anymore. Indeed, if we pose $D^R = 0$ (i.e. claimants cannot ask for compensation to the reporting firm), the value of damages which are liquidated is $W - F$. This corresponds to the value of the non-reporting firm's assets that remain after the payment of the sanction, whereas they would obtain a total compensation equal to $2\alpha^R D$ if the reporting firm is also asked to repay damages. By assumption, $W < F + \alpha^R D^{OR}$ and, since when $D^R = 0$ then $D^{OR} = 2D$, we have that $W - F < 2\alpha^R D$.

We can conclude that, if our proposal is implemented, the victims of those cartels that are not deterred and that are uncovered due to the LP might be worse off than under the legal regime envisaged by the EU and the US solutions.

However, even in this case, we can still say that the EU and the US solutions determine a suboptimal regime, as the Hungarian solution dominates them. This is easy to show. The critical discount factor is monotonically decreasing in $\alpha^R D^R$. Hence, optimal deterrence is achieved at a corner solution that depends on the constraint we pose on $\alpha^R D^R$, beyond the non-negativity constraint. Suppose that this constraint follows the policy objective of allowing the victims of cartels uncovered through a LP to obtain the same level of compensation that they can obtain under the US or the EU solutions under any possible circumstance. Now, we can have two possible situations. In the first, the non-reporting firm has sufficient assets to pay damages. In this case,

the optimal (corner) solution is $\alpha^R D^R = 0$. This entails $D^R = 0$, whereas both in the EU and in the US solution $D^R > 0$. The second possible situation is that in which the non-reporting firm has insufficient assets to pay the level of damages that would result under the alternative solutions, that is $W - F < 2\alpha^{NR} D$. In this case, the optimal corner solution is to set $\alpha^R = \alpha^{NR}$ and $D^R = 2D - (W - F)$. Hence, to maximize deterrence, under the constraint defined above, we can set $\alpha^R = \alpha^{NR}$ and $D^R = \max(0, 2D - (W - F))$. This solution is a fairly good representation of the Hungarian rules, at least as far as the liability of the immunity recipient is concerned.

Proposition 5: *If firms may be unable to compensate the cartel's victims without the contribution of the immunity recipient, the EU and the US solutions are strictly dominated by the Hungarian solution (i.e., the leniency recipient only becomes liable if all other cartel members go bankrupt).*

The above discussion shows that when there is a risk of firms' bankruptcy, a trade-off might exist between the deterrence objective and that of allowing cartels' victims to obtain full redress. In this case, the Hungarian rules on the civil liability of the immunity recipient may seem a good compromise. However, we can say something more, even if we restrict our attention to customers' welfare and leave aside any allocative efficiency considerations that would strongly suggest focusing only on the deterrence properties of the enforcement system. Indeed, the trade-off between deterrence and victims' compensation can be represented, in the customers' welfare space, as a trade-off between the welfare of the customers of potential cartels that do not form because they are effectively deterred, and the welfare of the customers of actual cartels that are uncovered due to an LP and subsequently obtain damages. As far as we know, nobody has ever argued that the welfare of actual victims is more important that the welfare of potential victims, and we cannot see what arguments could ever be used in favor of this

proposition. So, if the welfare of actual victims and that of potential ones is equally important, we should not be satisfied with a "second best" solution. In particular, we can check whether, or under which conditions, adopting our proposal rather than the Hungarian solution would make cartels' victims in general better off.

To make this assessment, let us assume that all cartels (actual and potential) cause the same level of harm to consumers (D) and, for the sake of this analysis, assume that the level of awarded damages (α^R) is the same in both legal regimes when a cartel is uncovered through a leniency application. The two solutions are equivalent if the assets of each (would-be) cartelist are sufficient to pay the fine and the awarded damages. Hence, we can restrict attention to the case in which victims can obtain the awarded damages only if the leniency applicant is held liable. In this case, our proposed solution deters more cartels but reduces the level of compensation obtained by the victims of actual cartels. Hence, we can define its consequences in the consumer welfare space as a benefit and a cost.

The benefit is the avoided consumer harm of the potential cartels that do not occur due to increased deterrence; the cost is the portion of consumer harm that is not compensated because the immunity recipient is not required to pay damages. Therefore, the benefit is:

$$(F(\underline{\delta}') - F(\underline{\delta}_H))D$$

where $\underline{\delta}'$ is the critical discount factor when our proposal is implemented, $\underline{\delta}_H$ is the critical discount factor when the Hungarian solution is in place, and F is the cumulative distribution function of firms' actual discount factor, δ. The cost, instead, is:

$$(1 - F(\underline{\delta}'))\beta\lambda\alpha^R D$$

where β is the fraction of undeterred cartels that are then reported by a leniency applicant, λ is the fraction of awarded damages that will not covered by the other cartelists,

and α^R is the portion of actual damages that is awarded by a court.

Our model does not allow us to say that the benefit of our proposal always exceeds its cost. This issue might be addressed empirically. However, we think that there are good reasons to believe that the benefit of our proposal is larger than its cost. First and foremost, customers of a potential but deterred cartel save the entire harm that the cartel would cause them (D), whereas those of an actual cartel are usually able to recover only a fraction of the harm they suffered. This is especially true if we consider that damage repayment is uncertain and takes time, and that civil action entails costs that are rarely fully reimbursed by the losing party. Therefore, α^R might be relatively low. Second, we are not aware of cases, at least in Europe, in which a damage action has determined the failure of one or more condemned defendants. From this, we can infer that the fraction of awarded damages that will not be paid if the immunity recipient is not liable (λ) is likely to be extremely low. Third, if the immunity recipient is granted immunity also on civil grounds, we suspect that the LP may become a tremendously powerful deterrence mechanism, so that the fraction of undeterred cartels ($1 - F(\underline{\delta'})$) is likely to be relatively low. Fourth, we have no evidence to say how many undeterred cartels fall apart because one of the members reports the cartel to a CA. What we can say is that in a stationary model such as ours, this number is zero (so that β is zero) because either the cartel is deterred or, if not deterred, is not reported.

All these considerations make us quite confident that our proposal would outperform the Hungarian solution if we give equal weight to the welfare of the actual victims of uncovered cartels and the welfare of the customers of potential cartels that do not occur because of increased deterrence.

4.4 Other extensions

An extension which is likely to increase the appropriateness of our suggested solution is to increase the number of cartel members. Keeping all else equal, an increase

in the number of competing firms should increase the risk that some other firms would take advantage of the LP and report the cartel's existence. Hence, the LP may be rendered extremely effective if the first applicant is further "rewarded" with a civil liability immunity, as the risk that a competitor would be lured by this reward increases exponentially with the number of active and colluding firms.

5 Conclusions

Does the pursuit of the primary goal of the public enforcement system, i.e. achieving an optimal level of deterrence of anticompetitive conducts, necessarily requires the amount of damages that claimants can expect to recover to be sacrificed? In this paper, we examine whether the solutions adopted by the EU and the US are the most appropriate ones, taking both objectives into consideration.

The position of the ECJ summarized in *Section 2* has the merit of clarifying that actions for damages initiated by the victims of an antitrust infringement may increase the level of deterrence. In this respect, public and private enforcement are not in conflict with each other. However, as far as hardcore cartels are concerned, the public interest has been pursued in many jurisdictions through the adoption of LPs. The legal debate has been centered on the question of whether damage actions can jeopardize the effectiveness of these programs. In our view, the legal debate has taken for granted that an inherent conflict exists between the proper functioning of an LP and private damage claims, so that any proper legislation necessarily implies a compromise between the interest of the public enforcement system and the interest of private cartel victims to be fully compensated. The recently adopted EU Directive on damage actions follows this path. Our analysis shows that a compromise is not actually needed: we do not have to limit the ability of cartel victims to recover their losses to preserve the effectiveness of an LP. In fact, damage actions can even improve the effectiveness of such programs.

The simple theoretical model discussed in the previous sections shows that as far

as the incentive compatibility constraint is concerned, the optimal solution is to limit as far as possible the risk for the immunity recipient to be condemned to pay damages, through reducing its level of liability. This maintains the deterrence properties of an LP implied by the incentive compatibility constraint. The EU Directive partially limits this liability, but it also limits the information that is available to the claimants. These two instruments (lowering the liability of the immunity recipients and restricting the available information) have different effects on deterrence and on the victims' ability to be fully compensated. Indeed, given that all cartelists are jointly and severally liable towards all of the cartel's victims, reducing the level of liability of the immunity recipient does not affect the amount of damages they can obtain. In contrast, limiting the evidence they can use in the damage action will certainly reduce the expected value of the final compensation. Hence, if we want to give concrete application to the legal principle that any victim has the right to be fully compensated, the best solution would be to grant complete access to all documents submitted by the immunity applicant and restrict (and possibly eliminate) the civil liability of the immunity recipient.

The US legislation is not optimal either, because it only detrebles damages for the successful amnesty applicant who, therefore, remains liable for single damages. The solution adopted in Hungary (which unfortunately is bound to be abandoned in favor of the EU Directive) is optimal when there is no risk of bankruptcy. Moreover, limiting the immunity applicant's civil liability will significantly reduce its incentive to disclose only the information that is strictly necessary for a successful leniency application and strategically avoid disclosing any information that would facilitate the hard work that the cartel's victims have to undertake when they claim damages.

Deterrence not only depends on the cartelists' incentives to deviate (and report), but also on the riskiness of continuing to collude. Recent laboratory evidence confirms that strategic risk is the main driver of deterrence. Our analysis shows that once risk dominance considerations enter the picture, our suggested solution dominates the Directive

to an even larger extent, in terms of deterrence effects. Hence, reducing the individual liability of the first reporting firm as much as possible and allowing claimants to obtain all the evidence collected during the administrative investigation is the optimal solution to pursue the interests of both public and private enforcement.

We have then considered the case in which firms may go bankrupt and therefore claimants cannot recover the entire awarded damages if the immunity recipient is not liable. Our analysis shows that a conflict between deterrence and the victims' right to compensation may exist in this case. However, the EU and the US solutions remain bad compromises; the Hungarian solution clearly dominates them as it performs better, as far as deterrence is concerned, and never reduces the amount of damages that victims can recover. Finally, we have argued that the trade-off between deterrence and the right to compensation can be interpreted as a trade-off between the welfare of customers of potential but deterred cartels, and the welfare of customers of actual cartels then reported by one of the conspirators. On that basis, we have put forward some arguments that support our claim that our proposal would entail a cost, in terms of expected reduced compensation of actual victims, that is largely outweighed by its benefit, which is the full "compensation" of customers of potential cartels that are never damaged as the cartels are effectively deterred.

6 Appendix I

6.1 Calculation of the Nash products

Let us first "summarize" our dynamic game into a two by two matrix with the expected payoffs in the four crucial states in *Table* 1. The collusive equilibrium is "strategic risk dominant" if each firm's equilibrium strategy is the best reply to the other firm's strategy of randomizing with equal probability between "Collude" and "Report".

We define the following value functions for the cases in which only the other firm reports and when both report:[19]

$$V_{OR}(C,R) = 0 - F - \alpha^R D^{OR}$$
$$V_{BR}(R,R) = \Pi - \frac{1}{2}F - \alpha^R D^{BR}$$

The game matrix is described in *Table 1*.

Table 1: Game matrix (1)

	C_j	R_j
C_i	V_{NR}, V_{NR}	V_{OR}, V_R
R_i	V_R, V_{OR}	V_{BR}, V_{BR}

By transforming the bimatrix-form of this game when agents establish a collusive agreement, the best response equivalent matrix is as shown in *Table 2* (see Harsanyi and Selten (1988) for more details on this transformation).

Table 2: Game matrix (2)

	C_j	R_j
C_i	$V_{NR} - V_R, V_{NR} - V_R$	0,0
R_i	0,0	$V_{BR} - V_{OR}, V_{BR} - V_{OR}$

The riskiness of the collusive agreement (γ) can be calculated using the "Nash

[19] When both firms deviate and report simultaneously, they will both set $P = P^{monopoly} - \varepsilon$ and split the market, receiving $\Pi^{deviate} = \Pi - \varepsilon$. It is assumed that $\varepsilon \simeq 0$.

products" of the two pure strategy equilibria. It can then be shown that collusion (C) is "strategic risk dominated" by "reporting" (R) when:

$$\gamma \equiv (V_{BR} - V_{OR})^2 - (V_{NR} - V_R)^2 > 0$$
$$\leftrightarrow (\Pi - \frac{F}{2} - \alpha^R D^{BR} + F + \alpha^R D^{OR})^2 - [\frac{\Pi - \rho(F + \alpha^{NR} D^{NR})}{1 - \delta} - 2\Pi + \alpha^R D^R]^2 > 0$$
$$\leftrightarrow \Pi - \frac{F}{2} - \alpha^R D^{BR} + F + \alpha^R D^{OR} + 2\Pi - \alpha^R D^R > \frac{\Pi - \rho(F + \alpha^{NR} D^{NR})}{1 - \delta}$$
$$\leftrightarrow \delta < \underline{\delta *} \equiv 1 - \frac{\Pi - \rho(F + \alpha^{NR} D^{NR})}{3\Pi + \frac{F}{2} + \alpha^R (D^{OR} - D^{BR} - D^R)}$$

$\underline{\delta *}$ can also be expressed as:

$$\underline{\delta *} = 1 - \frac{V'_{NR}}{V_{BR} - V_{OR} + V_R}$$

where V'_{NR} is the numerator of V_{NR}.

6.2 Comparative statics on $\delta *$

$$\frac{\partial \underline{\delta *}}{\partial D^R} = \frac{\alpha^R [\frac{\partial D^{OR}}{\partial D^R} - \frac{\partial D^{BR}}{\partial D^R} - 1][\Pi - \rho(F + \alpha^{NR} D^{NR})]}{[3\Pi + \frac{F}{2} + \alpha^R (D^{OR} - D^{BR} - D^R)]^2} = \frac{-2\alpha^R [\Pi - \rho(F + \alpha^{NR} D^{NR})]}{[3\Pi + \frac{F}{2} + \alpha^R (D^{OR} - D^{BR} - D^R)]^2} < 0$$

$$\frac{\partial \underline{\delta *}}{\partial \alpha^R} = \frac{[D^{OR} - D^{BR} - D^R + \alpha^R (\frac{\partial D^{OR}}{\partial \alpha^R} - \frac{\partial D^{BR}}{\partial \alpha^R} - \frac{\partial D^R}{\partial \alpha^R})][\Pi - \rho(F + \alpha^{NR} D^{NR})]}{[3\Pi + \frac{F}{2} + \alpha^R (D^{OR} - D^{BR} - D^R)]^2}$$
$$= \frac{[D^{OR} - D^{BR} - D^R][\Pi - \rho(F + \alpha^{NR} D^{NR})]}{[3\Pi + \frac{F}{2} + \alpha^R (D^{OR} - D^{BR} - D^R)]^2} > 0 \; iff \; D^{OR} > D^{BR} + D^R \leftrightarrow D^R < \frac{D}{2}$$

6.3 Difference in discount factors

The relative change in the discount factors derived from the ICC and the analysis of strategic risk, in the EU (*II*) and US solutions and our proposal is given by:

$$\frac{\underline{\delta*}^{(III)} - \underline{\delta*}^{(EU,US)}}{\underline{\delta*}^{(III)}} > \frac{\underline{\delta}^{(III)} - \underline{\delta}^{(EU,US)}}{\underline{\delta}^{(III)}} \leftrightarrow$$

$$\leftrightarrow \frac{1 - \frac{\Pi - \rho(F + \alpha^{NR} D^{NR})}{3\Pi + \frac{F}{2} + \alpha^{R(III)}(D - 2D^{R(III)})} - 1 + \frac{\Pi - \rho(F + \alpha^{NR} D^{NR})}{3\Pi + \frac{F}{2} + \alpha^{R(EU,US)}(D - 2D^{R(EU,US)})}}{1 - \frac{\Pi - \rho(F + \alpha^{NR} D^{NR})}{3\Pi + \frac{F}{2} + \alpha^{R(III)}(D - 2D^{R(III)})}} > \frac{1 - \frac{\Pi - \rho(F + \alpha^{NR} D^{NR})}{2\Pi - \alpha^{R(III)} D^{R(III)}} - 1 + \frac{\Pi - \rho(F + \alpha^{NR} D^{NR})}{2\Pi - \alpha^{R(EU,US)} D^{R(EU,US)}}}{1 - \frac{\Pi - \rho(F + \alpha^{NR} D^{NR})}{2\Pi - \alpha^{R(III)} D^{R(III)}}}$$

Given the optimal scenario, with $\alpha^{R(III)} = 1$ and $D^{R(III)} = 0$, this expression can be written as:

$$\leftrightarrow \frac{-\frac{1}{3\Pi + \frac{F}{2} + D} + \frac{1}{3\Pi + \frac{F}{2} + \alpha^{R(EU,US)}(D - 2D^{R(EU,US)})}}{1 - \frac{\Pi - \rho(F + \alpha^{NR} D^{NR})}{3\Pi + \frac{F}{2} + D}} > \frac{-\frac{1}{2\Pi} + \frac{1}{2\Pi - \alpha^{R(EU,US)} D^{R(EU,US)}}}{1 - \frac{\Pi - \rho(F + \alpha^{NR} D^{NR})}{2\Pi}}$$

In the EU solution, i.e. scenario II, we have: $\alpha^{R(EU)} = \alpha^{NR} < 1$ and $D = D^{R(EU)} > 0$, such that the above expression becomes:

$$\leftrightarrow \frac{-\frac{1}{3\Pi + \frac{F}{2} + D} + \frac{1}{3\Pi + \frac{F}{2} - \alpha^{NR} D}}{1 - \frac{\Pi - \rho(F + \alpha^{NR} D^{NR})}{3\Pi + \frac{F}{2} + D}} > \frac{-\frac{1}{2\Pi} + \frac{1}{2\Pi - \alpha^{NR} D}}{1 - \frac{\Pi - \rho(F + \alpha^{NR} D^{NR})}{2\Pi}}$$

$$\leftrightarrow \frac{1 + \alpha^{NR}}{\alpha^{NR}} \frac{\Pi + \rho(F + \alpha^{NR} D^{NR})}{\Pi + \frac{F}{2} + (2\Pi - \alpha^{NR} D)} > \frac{\Pi + \rho(F + \alpha^{NR} D^{NR}) + (\Pi + \frac{F}{2} + D)}{2\Pi - \alpha^{NR} D}$$

The above condition is true when α^{NR} is sufficiently small.

In the US solution, we have: $\alpha^{R(US)} = 1$, such that the above expression becomes:

$$\leftrightarrow \frac{-\frac{1}{3\Pi+\frac{F}{2}+D} + \frac{1}{3\Pi+\frac{F}{2}+1(D-2D^{R(US)})}}{1-\frac{\Pi-\rho(F+\alpha^{NR}D^{NR})}{3\Pi+\frac{F}{2}+D}} > \frac{-\frac{1}{2\Pi} + \frac{1}{2\Pi-D^{R(US)}}}{1-\frac{\Pi-\rho(F+\alpha^{NR}D^{NR})}{2\Pi}}$$

$$\leftrightarrow 2\frac{\Pi+\rho(F+\alpha^{NR}D^{NR})}{(2\Pi-D^{R(US)})+\Pi+\frac{F}{2}+D-D^{R(US)}} > \frac{\Pi+\rho(F+\alpha^{NR}D^{NR})+(\Pi+\frac{F}{2}+D)}{2\Pi-D^{R(US)}}$$

The above condition is true, provided that $\frac{D^{R(US)}}{D}$ is sufficiently small.

6.4 Discount factors with *T*

The new value functions become:

$$V_{NR}(T) = V_{NR} - \frac{\rho}{1-\delta}\frac{T}{2}$$
$$V_{BR}(T) = V_{BR} - \frac{T}{2}$$
$$V_R(T)(I) = V_R - T;\ V_R(T)(II) = V_R - \frac{T}{2};\ V_R(T)(III) = V_R - 0$$
$$V_{OR}(T)(I) = V_{OR} - 0;\ V_{OR}(T)(II) = V_{OR} - \frac{T}{2};\ V_{OR}(T)(III) = V_{OR} - T$$

As shown in subsection *(6.1)* in the Appendix, $\underline{\delta*}$ can be expressed as:

$$\underline{\delta*} = 1 - \frac{V'_{NR}}{V_{BR} - V_{OR} + V_R} \tag{3}$$

Therefore, the new discount factors are:

$$\underline{\delta*}^{(I)}(T) \equiv 1 - \frac{V'_{NR} - \rho\frac{T}{2}}{(V_{BR} - \frac{T}{2}) - (V_{OR} - 0) + (V_R - T)} = 1 - \frac{V'_{NR} - \rho\frac{T}{2}}{V_{BR} - V_{OR} + V_R - \frac{3T}{2}}$$

$$\underline{\delta*}^{(II)}(T) \equiv 1 - \frac{V'_{NR} - \rho\frac{T}{2}}{(V_{BR} - \frac{T}{2}) - (V_{OR} - \frac{T}{2}) + (V_R - \frac{T}{2})} = 1 - \frac{V'_{NR} - \rho\frac{T}{2}}{V_{BR} - V_{OR} + V_R - \frac{T}{2}}$$

$$\underline{\delta*}^{(III)}(T) \equiv 1 - \frac{V'_{NR} - \rho\frac{T}{2}}{(V_{BR} - \frac{T}{2}) - (V_{OR} - T) + (V_R - 0)} = 1 - \frac{V'_{NR} - \rho\frac{T}{2}}{V_{BR} - V_{OR} + V_R + \frac{T}{2}}$$

The difference between the discount factors of scenarios *III* and *II* is:

$$\begin{aligned}
&\underline{\delta*}^{(III)}(T) - \underline{\delta*}^{(II)}(T) = \\
&= 1 - \frac{V'_{NR} - \rho\frac{T}{2}}{V_{BR} - V_{OR} + V_R + \frac{T}{2}} - 1 + \frac{V'_{NR} - \rho\frac{T}{2}}{V_{BR} - V_{OR} + V_R - \frac{T}{2}} \\
&= \frac{V'_{NR} - \rho\frac{T}{2}}{V_{BR} - V_{OR} + V_R - \frac{T}{2}} - \frac{V'_{NR} - \rho\frac{T}{2}}{V_{BR} - V_{OR} + V_R + \frac{T}{2}} \\
&= \frac{(V'_{NR} - \rho\frac{T}{2})[V_{BR} - V_{OR} + V_R + \frac{T}{2} - V_{BR} + V_{OR} - V_R + \frac{T}{2}]}{(V_{BR} - V_{OR} + V_R + \frac{T}{2})(V_{BR} - V_{OR} + V_R - \frac{T}{2})} \\
&= \frac{V'_{NR}T - \rho\frac{T^2}{2}}{(V_{BR} - V_{OR} + V_R)^2 - \frac{T^2}{4}}
\end{aligned}$$

The derivative of this difference with respect to T is:

$$\begin{aligned}
&\frac{\partial[\underline{\delta*}^{(III)}(T) - \underline{\delta*}^{(II)}(T)]}{\partial T} = \\
&= \frac{(V'_{NR} - \rho T)[(V_{BR} - V_{OR} + V_R)^2 - \frac{T^2}{4}] + \frac{T}{2}(V'_{NR}T - \rho\frac{T^2}{2})}{[(V_{BR} - V_{OR} + V_R)^2 - \frac{T^2}{4}]^2} \\
&= \frac{(V'_{NR} - \rho T)(V_{BR} - V_{OR} + V_R)^2 + \frac{T^2}{4}V'_{NR}}{[(V_{BR} - V_{OR} + V_R)^2 - \frac{T^2}{4}]^2} \\
&> 0
\end{aligned}$$

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