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**INTERMITTENT COLLUSIVE AGREEMENTS:  
ANTITRUST POLICY AND BUSINESS CYCLES**

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# Intermittent collusive agreements: antitrust policy and business cycles

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## Abstract

In this article we study collusive strategies when firms face random demand fluctuations. This work analyzes the optimal level of fines in times of crisis. We assume that detection probability may or may not depend on collusive price. When cartel is detectable irrespective of price they are less stable in booms than in recessions and prices can be counter-cyclical. This requires to set the highest achievable fines. By contrast if detection probability depends on collusive prices intermittent collusive strategy can be implemented in which firms collude on periods for which it is the most profitable strategy. Firms can either charge procyclical or countercyclical collusive prices. Optimal level of fines depends on demand state and it can be discounted if demand is low to support marginal deterrence effect or during booms to decrease the harmfulness of anticompetitive conduct.

**Keywords:** Collusion, antitrust policy, business cycles.

**JEL:** K42, L22, L41.

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# 1 Introduction

This article discusses the relevance of state-dependent antitrust fines. Facing fluctuating demand, cartel members can set the monopoly price for each state of demand or may decide to interrupt collusion in one of the demand states to avoid detection in that state since expected cartel detection and dissolution risk can dominate collusive payoffs. Collusive behaviors rely on state-dependent fines. Antitrust authority may find it preferable to adjust antitrust fines to business cycles in order to modify the firms collusive strategy. In such cases cartels may choose to hibernate in some periods leading to increased consumer surplus during those periods or, on the contrary, they can collude whatever the state of demand leading to increased detection probability. The implementation of state-dependent fines may influence cartel members choice between intermittent collusive strategies (the cartel loses profit in one state but increases its survival rate) and constant collusive strategy with a shorter duration.

Our model is based on the approach adopted by Rotemberg and Saloner (1986) [RS henceforth] in which we include an antitrust authority. We explore strategies implemented by collusive firms when they face random demand fluctuations. Then we discuss the optimal level of cartel fines in line with business cycle. Our paper encompasses two strands of literature. The first is the literature tying collusion sustainability and random fluctuating demand. The second is the analysis on the adaptation of competition policy enforcement to cyclical changes of economy.

A recurring issue in industrial organization deals with sustainability of collusive agreements under business cycles. Some studies point out that recessions result in weakening of collusive sustainability whereas others underline the opposite result putting forward the argument that incentives to deviate from cartel are stronger during booms. We review major contributions on this topic in the next section. Our article contributes to this literature by including an active antitrust authority in RS. Antitrust authority is intended to fight collusion and once detected, cartels are fined and dissolved forever. Two different scenarii of cartel enforcement are studied. Under the first assumption (A1) implementation of cartel requires governance structure leading to hard evidence which can be detected regardless of price. Detection probability remains constant even if the cartel price equals marginal cost. Under this assumption primarily used to provide a benchmark, results are consistent with RS: collusive agreements are less likely to occur during booms. Under the more realistic assumption A2, detection probability is price dependent.<sup>1</sup> For the sake of simplicity we assume that detection probability is zero when firms set price equal to marginal cost and is increased to  $\rho$  for higher price. For some parameters values firms can choose to implement collusion only during booms or recessions. Since they play an infinitely game cartel detection is inescapable. Firms face a tradeoff between sustaining collusion regardless of demand to benefit right away from higher price or implementing intermittent collusive strategy (firms set collusive price only when it is the most profitable strategy) leading higher but later expected profit. Consequently firms may choose to set higher price only during booms and charge the marginal cost if demand is low, these results differ from RS. Firms may also choose the opposite strategy if antitrust fines depend on business cycles and are discounted during low demand period. Finally if expected collusive profit

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<sup>1</sup>Higher price may make customers suspicious that a cartel has formed.

is similar for both demand states firms may choose to collude until cartel is detected and dissolved. Collusive firms' strategies and price fluctuation according to business cycles rely on cartel enforcement including the imposition of fines. Our paper contributes to the body of literature in introducing a new collusive strategy where firms implement intermittent cartel. Some previous studies allow firms to decrease the degree of collusion but without reverting to competitive equilibrium.

This work contributes also to the determination of the optimal level of fines during economic or financial crisis. Maintaining or releasing competition rules is a constant issue during each economic crisis. Arguments in favor of releasing competition rules are two-fold: (1) larger fines in times of crisis may induce increased bankruptcy and (2) collusive behavior allows a faster and more efficient reduction of over-capacities and provides industry to adapt more quickly to a new economic environment. Some specific clauses exist in the European Union such as a reduced antitrust fines if companies can be made bankrupt because of punishment.<sup>2</sup> The role of competition policy is to promote competition not eliminate firms from the market. European Union guidelines provide potential cooperation among competitors during crisis. Barjot and Schröter (2013) and Barjot (2014) give as an example the capacity reduction agreement on artificial fibres during the 1980s, providing an answer to the structural crisis facing the European chemical industry, without using government funds. They point out that before 1945 cartels were legal in Europe and were considered to be in societies' interest (economics shock absorption, survival of businesses and jobs,...). The US antitrust authorities take a similar approach during some major crisis. As a consequence of the financial crisis of 1929 the National Industrial Recovery Administration<sup>3</sup> set up in 1933 by the US antitrust authorities putted as an aside the antitrust legislation. September 11 attacks committed in 2001 caused a serious decline in airline demand particularly in the United States. To respond to this drop the U.S. Department of Transportation allowed<sup>4</sup> an agreement between two Hawaiian airlines which received an antitrust immunity allowing them to coordinate air travel capacity and prices. Prices rose during the period of coordination and they still remained high after immunity expired (Blair, Mak and Bonham, 2007 ; Kamita, 2010). The temptation of releasing competition rules reoccurs regularly during crisis periods.<sup>5</sup> We put forward a third argument (quite different from the two previous reasons) to reduce fine during recessions, which relies on marginal deterrence. Antitrust authority may induce the cartel to sustain collusive agreements even during recession since the consumer loss is lower than during high period demand and this increases the detection probability and cartel dissolution.

To the best of our knowledge Fabra and Motta (2013) is the main paper which theoretically analyzes optimal lower fines during recessions. They consider an incumbent firm which, facing a potential entrant, can take a conduct violating antitrust laws. Antitrust authority can launch investigations and impose corporate and managerial fines. They show that both fines must be applied: a reduced corporate fine to decrease

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<sup>2</sup>Some illustrative examples are provided in Fabra and Motta (2013).

<sup>3</sup>The National Industrial Recovery Act was promoted to help the nation recover from the Great Depression and to abolish "unfair competition" on the basis of voluntary agreements established by firms which set, inter alia, minimal wages. This law was declared unconstitutional in 1935. However later legislation incorporated many elements of the previous law. Cole and Ohanian (2004), in a general equilibrium analysis, present data that show very little antitrust enforcement by the DoJ after 1935 and find that this more lenient cartelization policy is a key factor behind the weak recovery.

<sup>4</sup>Against the consultative advice undertaken by the Department of Justice

<sup>5</sup>However this toleration of crisis cartels is not systematically in place. Ghosal and Gallo (2001) show that antitrust case activity of the US Department of Justice is countercyclical.

the risk of social cost of bankruptcy and a managerial fine to revert to the initial deterrence level. They argue that lower fines during recessions are sometimes optimal. First it is harder to achieve deterrence in booms (anticompetitive practice is more benefit) then higher fine must be applied. Second the risk of bankruptcy facing the firm if the fine is high is lower during booms than recessions, then optimal fines can be lower during recessions. Finally they show that varying policy according to the demand state can be welfare-maximizing. In contrast to this paper we consider a dynamic model. Both fines act on collusive sustainability constraints: fine imposed during recessions may influence collusive strategy in booms (and vice versa). Another relevant difference relates to the marginal deterrence effect which is not introduced in their model since only one anticompetitive strategy is achievable. Unlike their paper, firms can implement different collusive strategies and besides the traditional deterrence effect of fines they can also influence collusive strategy and related social welfare. This marginal deterrence effect produces the most interesting results under the assumption A2. Only one collusive strategy is implemented under the first assumption (A1) leading to set the highest achievable fines. Under assumption A2 fines produce a deterrent effect on cartel formation (this induces highest level of punishment) and a marginal deterrent effect relying on different anti-competitive effects. This latter point may lead authority to vary fines according to demand state. Contrary to earlier findings on traditional marginal deterrence<sup>6</sup> the seriousness of infringements depends on parameters values then, relative to a constant collusive strategy, intermittent cartel can lead to higher or lower expected social welfare. Setting maximum fine in one state and zero fine in the other can be optimal to strengthen the marginal deterrence effect but this is not in line with the traditional deterrence effect on cartel formation. Then antitrust authority must balance these different objectives (deter the cartel formation and decrease the harmfulness of anticompetitive conduct) and imposing one maximum fine and an other lower fine can be optimal. In our model, reducing fines if demand is low can be optimal but authority may instead discount fines during booms to induce the implementation of a less harmful intermittent collusive strategy.

This article is organized as follows. In the next section we underline the related literature. Then we describe our model (section 3). Section 4 reports the results obtained under assumption A1. They serve as a benchmark to present in section 5 the results obtained with the alternative hypothesis. The conclusion follows in section 6.

## 2 Related literature

This paper contributes to two strands of literature. The first is the literature tying collusion sustainability and random fluctuating demand. The second analyzes the effects of fines on collusive strategies.

### 2.1 Collusion sustainability and business cycles

The relationship between collusion and business cycles is not a new issue. Kleinwächter (1883), the founder of cartel theory, describes cartels as children of distress ("Kinder der Not") since they might arise as the

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<sup>6</sup>Stigler (1970), Shavell (1992), Wilde (1992), Mookherjee and Png (1994) and Friehe and Miceli (2014).

response to economic downturn in order to offset the drop in the price. Afterwards the literature on the relationship between cartel sustainability and business cycle is quite extensive.

In contrast to the argument that cartels arise during economic downturn, Green and Porter (1984) suggest that low demand periods may trigger transitory price wars. Because of the inability of the firms to determine if low demand is induced either by economic situation or by a deviation of the collusive path, period of weak demand requires punishment to dissuade the cheaters.<sup>7</sup>

Our article is in line with the works initiated by Rotemberg and Saloner (1986) [RS]. They argue that cartels are likely to behave more competitively in periods of high demand since deviating from the collusive agreement results in maximum profit. This result is partly due to the fact that demands over various periods are uncorrelated, then future expected profit (whether firms keep on collusion or deviate) is independent of current demand and cartel deviation is more attractive if such demand is high.

Several studies check the robustness of the results obtained by RS. Kandori (1991) includes demand correlation over time and demonstrates that if the discount factor tends to unity or is close to  $\frac{n-1}{n}$  ( $n$  is the number of firms) in which case the no deviation constraint is binding, prices disclose the same counter-cyclical movement as in RS. Haltiwanger and Harrington (1991) allow for cyclical demand instead of random demand. They assume that movements in market demand are fully anticipated but each cycle is composed of finite number of periods. In their model firms can more easily collude during falling demand which does not necessarily contradict results of RS: the gain from deviation is highest when demand is strongest and begins to fall when demand is decreased.

Bagwell and Staiger (1997) assume that the level of market demand swaps between slow- and fast-growth states, and the transition between states is determined by a Markov process. They show that if demand growth rates are strongly [weakly] correlated over time then collusion is easier to sustain if demand growth rate is strong [low]. Bernhardt and Rastad (2016) analyze collusion under demand uncertainty by risk-averse cartel and overturn the RS results when cartel members are risk adverse and face positive fixed operating costs. Risk aversion implies that marginal gain from cheating on the cartel declines as demand is increasing. Fixed operating cost strengthens this effect and allows to provide contradictory results of RS for some parameters values.

Staiger and Wolak (1992), Fabra (2006), Knittel and Lepore (2010) and Paha (2017) explore collusive pricing with capacity constrained firms in the presence of demand uncertainty. Capacity constraint may constrain deviation opportunities of collusive firms but also potential retaliation against deviating firm. The link between collusive opportunities and demand state depends on either firm's capacities (if they are exogenous) or their expenditures (if they are endogenous).

Montero and Guzman (2010) analyze collusive agreement under demand uncertainty but the model differs from RS in several ways. In their model collusive agreement is sustained by large firms in the presence of a

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<sup>7</sup>In the model presented in Green and Porter (1984), firms can not observe the demand shock or other firm's quantity choices. Only the equilibrium price is public information. Since low prices can reflect demand conditions or overproduction by competitors, then, to ensure that punishment mechanisms are credible, the regime switches to a reversionary episode in which firms compete before to switch back to collusion.

competitive fringe. Then cartels may lead to two opposite effects. First members of the cartel may reduce their production so as to increase equilibrium price. Second cooperation among members may lead to output-expanding strategies with the purpose of decreasing the production of the competitive fringe. The dominant effect depends on the demand state.

These previous studies assume that the number of firms is fixed, instead of Eswaran (1997) and Bagliano and Dalmazzo (1999) who explicitly include in the context of RS the possibility of bankruptcy in recessions. Then cartels may be more difficult to sustain during recessions since the risk of bankruptcy induces firms to place a greater weight on immediate profits. To alleviate this problem, Eswaran (1997) allows for state-dependent market sharing strategies.<sup>8</sup>

Vasconcelos (2008) points out that market growth may trigger future entry.<sup>9</sup> Potential entrant may alter sustainability of collusive agreement. Entry takes place earlier in growing market as the entrant profit is higher if collusive agreement is already sustained than if it is dissolved in response to deviation. Then deviation not only provides higher current profit, but also delays potential entry. Subsequently collusion may be more difficult to sustain in growing markets when the number of firms is endogenous.

Our article contributes to this literature by including an active antitrust authority. We show that, subject to certain conditions, firms can implement intermittent collusive strategy: cartels can be bracketed for some periods (often, but not exclusively, when demand is low). This type of intermittent collusive strategy has never been studied before (in previous mentioned papers degree of collusion can be affected but firms do not switch to competitive equilibrium).

## 2.2 Marginal deterrence of collusion

Articles dealing with the fight against cartels mainly focus on cartel deterrence. Few studies analyze marginal deterrence effect: even if collusive agreements are not fully deterred the gravity of offense can be reduced with appropriate competition policy and antitrust fines.<sup>10</sup>

Detering the formation of collusive agreements requires the maximal level of fines. But if perfect deterrence is not achievable authorities may set level of fines depending on prices in order to decrease them and thus damages suffered by consumers. This issue is studied by Souam (2001) and Pénard and Souam (2002) in static model (disregarding the no deviation constraint) and Houba, Motchenkova and Wen (2010, 2018) in a dynamic setting.

There is an extensive literature on monetary penalty regimes which concentrates on welfare properties of such regimes<sup>11</sup> and some of these contributions show that revenue-based fines can induce cartel to set a

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<sup>8</sup>This adjusting market share eliminates the risk of bankruptcy for firms with financial weakness since the other producers can curtail their own products if demand is low to ensure the viability of these firms. In return they obtain larger market shares when demand is high.

<sup>9</sup>See also Correia-da-Silva, Pinho and Vasconcelos (2016).

<sup>10</sup>See Stigler (1970), Shavell (1992), Wilde (1992), Mookherjee and Png (1994) and Friehe and Miceli (2014) for studies on traditional marginal deterrence applied to crime.

<sup>11</sup>See e.g. Harrington (2005, 2010), Buccirosi and Spagnolo (2007), Houba et al. (2010), Bageri et al. (2013), Dargaud et al. (2016), Katsoulacos et al. (2015).



price above the monopoly price.<sup>12</sup> This anticompetitive effect can be offset if method of computations of fines is revised (Katsoulacos, Motchenkova and Ulph, 2020a) or if civil damages are included (Katsoulacos, Motchenkova and Ulph, 2020b).<sup>13</sup>

Harrington (2004) indicates that methods for computing antitrust damages and especially for estimating the standard non-collusive price can influence post-cartel prices.

Houba, Motchenkova and Wen (2015) analyze how leniency programs affect cartel pricing and Emons (2020) studies the impact of such programs on the degree of collusion.<sup>14</sup>

Our contribution is quite different from the previous papers which mainly focus on cartel price when deterrence effect is not prevailing. Since we assume that fine does not depend on collusive price we disregard this feature. However we consider that fines may depend on business cycles and then marginal deterrence effect does not deal directly with cartel price (even if it is indirectly impacted) but with the number of demand states in which cartels operate. Another feature of our article is that the ranking of the impact of collusive strategies on welfare depends on parameters values unlike the previous papers for which lower collusive price has a positive effect on welfare.

Our article features some similar points to those raised by Reuter (2017). He extends Green and Porter (1984) model by involving the possibility of a trade association in collusion. This allows firms to receive a signal about the aggregate demand state and this changes the length of price war. However cartel detection is increased then expected duration of cartel is reduced. As in our article several collusive strategies are achievable and expected fines set by antitrust authority (fine can be discounted or not for cartels which operate without trade association) impact the choice of the strategy adopted. Antitrust authorities face a trade-off between inducing collusive firms to avoid trade association in order to increase frequency of price wars and to decrease expected collusive prices or inducing firms to fall back on trade association to boost detection probability and decrease the expected length of collusive agreement. Although our article similarly highlights a trade-off for antitrust authority our model deviates however in a number of points from Reuter (2017). We assume perfect information, we do not include trade association and, more importantly, we focus on fines based on business cycles.

### 3 The Model

We consider an  $n$ -firm Bertrand competition setting over an infinite time horizon. Firms produce homogeneous good with the same marginal cost  $c$ . At each period, firms can decide to reach a collusive agreement. Collusive outcomes are modelled on a grim trigger basis: as soon a firm deviates from the agreement, all firms will play competitively forever.<sup>15</sup>

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<sup>12</sup>Bageri, Katsoulacos and Spagnolo (2013), Katsoulacos, Motchenkova and Ulph (2015).

<sup>13</sup>Katsoulacos, Motchenkova and Ulph (2019) provide an overview of the impact of different computations of fines on collusive prices.

<sup>14</sup>Multimarket colluding firms pick the breadth of collusion and then the fraction of a continuum of markets on which they collude. Higher breadth leads to higher detection probability.

<sup>15</sup>If we consider Nash equilibria of static game, at least two firms set price equal to marginal cost and others can choose higher prices. In order to avoid that authority could think that those higher prices reflect collusive strategies, we assume that without

Fluctuating demand is characterized by the following function:  $Q(p, \theta)$  where  $p$  is the industry price and  $\theta$  is a discrete random variable with the set of values:  $\{\theta_l, \theta_h\}$ . Low [high] shock  $\theta_l$  [ $\theta_h$ ] occurs with probability  $\mu$  [ $1 - \mu$ ]. As in RS we assume that shocks are independently and identically distributed. The following assumptions apply:  $\forall p: Q(p, \theta_h) \geq Q(p, \theta_l)$ ;  $\frac{\partial Q}{\partial p}(\cdot) \leq 0$  and  $\frac{\partial^2 Q}{\partial p^2}(p, \theta)p + 2\frac{\partial Q}{\partial p}(p, \theta) < 0$ . Thence monopoly price and profit ( $p^m(\theta)$  and  $\pi^m(\theta)$ ) are well-defined. We keep demand function in the most general form throughout this article but we use sometimes a specific form:  $Q(p, \theta) = \theta(A - p)$  in order to illustrate the results.

We consider an antitrust authority intended to detect and fight collusion. Each period, an active cartel is detected with probability  $\rho$  which is not price dependent if firms set higher price than static equilibrium price<sup>16</sup> (equal to marginal cost). Antitrust authority can launch investigations during deviation period if price exceeds marginal cost.<sup>17</sup> When colluding firms set price equal to marginal cost, two cases are analyzed:

Assumption A1: detection probability remains  $\rho$ . This assumption is based on the following rationale. Implementation of collusive agreements requires governance structure in which firms delegates meet at the beginning of each period in order to fix the price according to  $\theta$ . This generates hard evidence which can be found by the authority whatever the price is.

Assumption A2: detection probability is zero. We could assume that antitrust authority launches investigation only if consumers complain and this is not the case if price is competitive and thus when collusive agreement is bracketed.

We favor the latter assumption which seems more realistic, assumption A1 is primarily used to provide a benchmark.

If a cartel is detected, authority launches investigation which leads to successful prosecution that results in a fine  $f(\theta) \in [0, F(\theta)]$ . Prior to starting the game, antitrust authority discloses the amount of fines incurred. Fine can be state-contingent ( $f_l \equiv f(\theta_l)$  may be different from  $f_h \equiv f(\theta_h)$ ) but never exceeds the statutory maximum  $F(\theta)$ . Cartels are dissolved once they have been convicted and firms can not collude again. Firms, consumers and antitrust authority face the same discount factor  $\delta$ .

Denote the instantaneous profit and consumer surplus by  $\pi$  and  $cs$  and the flow of discounted profits and consumer surplus by  $\Pi$  and  $CS$ . Superscripts  $m$  and  $nc$  designate respectively the monopoly and non cooperative situation.

## 4 Constant detection probability

Collusive outcomes are modelled on a grim trigger basis (Friedman, 1971): as soon a firm deviates from agreement or if cartel is condemned, all other firms will play competitively forever and obtain  $\Pi^{nc} = 0$ .

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collusion, all firms play Bertrand Nash equilibrium and choose  $p = c$ .

<sup>16</sup>Firm setting higher price than marginal cost faces the risk of being fined even if its demand is 0. We do not consider the possibility that some firms, alternatively, do not produce during given time to remove the potential fine.

<sup>17</sup>As in many other papers (Spagnolo (2004), Buccirosi and Spagnolo (2007), Chen and Rey (2013), Jensen and Sorgard (2016), Dargaud and Jacques (2015, 2020)) we assume that the cartel can still be detected in a period of defection.

Denote the global cartel profit by  $\pi^*(\theta)$ . Deviating firm  $i$  obtains:  $\pi_i^d(\theta) = \pi^*(\theta) - \rho f(\theta)$  since it captures global demand by setting  $p_i = p^* - \varepsilon$ . Discounted deviation profit is the same:<sup>18</sup>  $\Pi^d(\theta) = \pi^*(\theta) - \rho f(\theta)$ .

Firms strategy on collusive path may depend on the value of  $\delta$ . We first assume that  $\delta$  is sufficiently high that collusion at the monopoly price is sustainable whatever the state of demand. Then we consider reduced values of  $\delta$  for which collusive agreements could be sustainable at lower price.

#### 4.1 High discount factor

According to assumption A1,  $\rho$  and  $f(\theta)$  are not price dependent then firms choose the monopoly price  $p = p^m$  if such price is sustainable. We define the constant strategy of setting monopoly price regardless of demand as the "C strategy".

Associated discounted profits are:

$$\begin{aligned}\Pi^C &= \mu \left( \frac{\pi^m(\theta_l)}{n} - \rho f_l \right) + (1 - \mu) \left( \frac{\pi^m(\theta_h)}{n} - \rho f_h \right) + \delta(1 - \rho) \Pi^C \\ \Leftrightarrow \Pi^C &= \frac{\mu \left( \frac{\pi^m(\theta_l)}{n} - \rho f_l \right) + (1 - \mu) \left( \frac{\pi^m(\theta_h)}{n} - \rho f_h \right)}{1 - \delta(1 - \rho)}\end{aligned}$$

We have to determine  $\delta^C$  such as firms behave like a monopoly for each state of demand.  $\delta^C = \max(\delta_l^C, \delta_h^C)$  where  $\delta_l^C$  and  $\delta_h^C$  are computed according to low and high demand respectively.

**Low demand:** Collusion on the monopoly price is sustainable iff:

$$\begin{aligned}\frac{\pi^m(\theta_l)}{n} - \rho f_l + \delta(1 - \rho) \Pi^C &\geq \pi^m(\theta_l) - \rho f_l \\ \Leftrightarrow \delta \geq \delta_l^C &\equiv \frac{(n - 1) \pi^m(\theta_l)}{(1 - \rho) \{(\mu + n - 1) \pi^m(\theta_l) - n\mu\rho f_l + (1 - \mu) [\pi^m(\theta_h) - n\rho f_h]\}}\end{aligned}$$

**High demand:** The collusion sustainability condition reads as:

$$\begin{aligned}\frac{\pi^m(\theta_h)}{n} - \rho f_h + \delta(1 - \rho) \Pi^C &\geq \pi^m(\theta_h) - \rho f_h \\ \Leftrightarrow \delta \geq \delta_h^C &\equiv \frac{(n - 1) \pi^m(\theta_h)}{(1 - \rho) \{[\mu(\pi^m(\theta_l) - n\rho f_l) - (1 - \mu)n\rho f_h] + (n - \mu) \pi^m(\theta_h)\}}\end{aligned}$$

Increasing  $f_l$  and/or  $f_h$  makes collusion more difficult to sustain regardless of demand state.

The following proposition establishes a comparison of collusion sustainability relative to business cycles.

**Proposition 1** *Under assumption A1, if collusion at the monopoly price is sustainable then collusive agreements are more difficult to sustain in booms than in recessions.*

<sup>18</sup>Notice that these profits are the same for any deviating firm given the model's symmetry, allowing us to drop index  $i$  to simplify notation.

**Proof.**

$$\delta_h^C \geq \delta_l^C \Leftrightarrow (1 - \mu) \left[ \frac{\pi^m(\theta_h)}{n} - \rho f_h \right] + \mu \left[ \frac{\pi^m(\theta_l)}{n} - \rho f_l \right] \geq 0$$

This condition is always checked if  $\Pi^C > 0$ . Otherwise collusion is not sustainable and discount factors comparison is irrelevant. ■

However  $\frac{\pi^m(\theta_l)}{n} - \rho f_l$  and  $\frac{\pi^m(\theta_h)}{n} - \rho f_h$  can be negative. Firms cannot delete potential fines by temporarily implementing competitive behavior, then expected fines  $\rho f_l$  and  $\rho f_h$  seem fixed costs borne as long as cartel is active.

This result is consistent with RS. We assume that firm can be fined during deviation period then expected fine is the same under collusion and deviation. Therefore if firms rely on current profit to decide if they stick to collusive price they make the same choice as in RS's model without fine.<sup>19</sup>

## 4.2 Middle discount factor

If  $\delta_l^C < \delta < \delta_h^C$  monopoly price is not sustainable if demand is high (and thus under the C strategy) but lower price can be sustainable (higher than the marginal cost).<sup>20</sup>

If demand is low collusive price and individual profit are:  $p(\theta_l) = p^m(\theta_l)$  and  $\frac{\pi^m(\theta_l)}{n}$ .

If demand is high  $p^*$  and  $\pi^*$  stand for collusive price and global profit, they are computed maximising discounted collusive profit subject to the no-deviation constraint.

Expected discounted profit is equal to:

$$\Pi^{C*} = \frac{\mu \left( \frac{\pi^m(\theta_l)}{n} - \rho f_l \right) + (1 - \mu) \left( \frac{\pi^*}{n} - \rho f_h \right)}{1 - \delta(1 - \rho)}$$

$\Pi^{C*}$  is increasing in  $\pi^*$ , then firms choose the maximum sustainable price. The collusion sustainability condition reads as:

$$\frac{\pi^*}{n} - \rho f_h + \delta(1 - \rho) \Pi^{C*} \geq \pi^* - \rho f_h$$

The constraint is binding then:

$$\pi^* = \frac{n\delta(1 - \rho) \left[ \mu \left( \frac{\pi^m(\theta_l)}{n} - \rho f_l \right) - (1 - \mu) \rho f_h \right]}{n - 1 - \delta(1 - \rho)(n - \mu)}$$

$\pi^*$  is decreasing in  $f_l$  and  $f_h$ , so is collusive price  $p^*$ .

Then we obtain the following proposition which discloses that collusive price implemented during high demand period is affected by amounts of fines  $f_h$  and  $f_l$ .

**Proposition 2** *During booms, collusive price  $p^*$  is a decreasing function of the fines  $f_h$  and  $f_l$ .*

<sup>19</sup>It would be different if deviating firm could not be fined, considering for instance leniency program.

<sup>20</sup>This case is similar to RS.

Even if  $f_h$  and  $f_l$  are too weak to deter collusive agreements, they can cushion their effects by decreasing price during booms.

Expected discounted profit is:

$$\Pi^{C*} = \frac{[n - 1 - \delta(1 - \rho)(n - 2\mu + 1)]\mu\pi^m(\theta_l) - [1 - \delta(1 - \rho)](n - 1)n\rho[\mu f_l + (1 - \mu)f_h]}{[1 - \delta(1 - \rho)][n - 1 - \delta(1 - \rho)(n - \mu)]}$$

### 4.3 Level of fines

On the basis of assumption A1, increasing  $f_l$  and/or  $f_h$  makes collusion more difficult to sustain. Moreover  $p^*$  is decreasing in  $f_l$  and  $f_h$ . The next proposition establishes optimal level of fines.

**Proposition 3** *Under assumption A1, optimal policy is to set the highest achievable fines:  $f_h = F_h$  and  $f_l = F_l$ .*

As in many studies dealing with economic analysis of crime, optimal policy requires the maximum level of fine. If maximum level of fines does not depend on business cycle ( $F_h = F_l$ ), nor are fines imposed on firms.

## 5 Price-dependent detection probability

According to assumption A2, cartel can be detected and condemned only if price exceeds marginal cost. In this case  $\rho$  and  $F$  are not price dependent then colluding firms choose monopoly price. For periods in which price equals marginal cost firms can not be convicted. We start with characterization of collusive agreements according to the level of fines. Then we rank collusive strategies in accordance with consumers surplus and global welfare. Finally we show that setting only one maximum fine can be optimal. These results are discussed with a general demand function and then illustrated with a specific one.

### 5.1 Collusive strategies

As in the previous section we first assume that  $\delta$  is sufficiently high that cartel can choose the monopoly price. Then we consider lower values of  $\delta$ . Firms choose between three different collusive strategies: monopoly price can be set regardless of demand (C strategy), only if demand is high (H strategy) or low (L strategy).

#### 5.1.1 Constant strategy

$\Pi^C$  is the same as in the previous section but expected fines  $\rho f_l$  and  $\rho f_h$  are now quasi-fixed costs that must be paid only if firms decide to set higher price than marginal cost. Firms prefer to switch to the H or L strategies if:  $\frac{\pi^m(\theta_l)}{n} - \rho f_l < 0$  or  $\frac{\pi^m(\theta_h)}{n} - \rho f_h < 0$ . In the opposite case, the C strategy is similar to the one previously described.

### 5.1.2 Intermittent strategies

When collusion is intermittent firms playing the H [L] strategy set monopoly price only if demand is high [low], otherwise they charge marginal cost.

Discounted profits are:

$$\begin{aligned}\Pi^H &= \mu\delta\Pi^H + (1-\mu)\left[\frac{\pi^m(\theta_h)}{n} - \rho f_h + \delta(1-\rho)\Pi^H\right] &\Leftrightarrow \Pi^H &= \frac{1-\mu}{1-\delta+(1-\mu)\delta\rho}\left[\frac{\pi^m(\theta_h)}{n} - \rho f_h\right] \\ \Pi^L &= (1-\mu)\delta\Pi^L + \mu\left[\frac{\pi^m(\theta_l)}{n} - \rho f_l + \delta(1-\rho)\Pi^L\right] &\Leftrightarrow \Pi^L &= \frac{\mu}{1-\delta+\mu\delta\rho}\left[\frac{\pi^m(\theta_l)}{n} - \rho f_l\right]\end{aligned}$$

Firms playing the H [L] strategy can have incentives to deviate from the cartel if demand is high [low] but not otherwise, collusion sustainability conditions are:

$$\begin{aligned}\frac{\pi^m(\theta_h)}{n} - \rho f_h + \delta(1-\rho)\Pi^H \geq \pi^m(\theta_h) - \rho f_h &\Leftrightarrow \delta \geq \delta^H \equiv \frac{(n-1)\pi^m(\theta_h)}{[n(1-\rho+\mu\rho)-\mu]\pi^m(\theta_h)-n(1-\rho)(1-\mu)\rho f_h} \\ \frac{\pi^m(\theta_l)}{n} - \rho f_l + \delta(1-\rho)\Pi^L \geq \pi^m(\theta_l) - \rho f_l &\Leftrightarrow \delta \geq \delta^L \equiv \frac{(n-1)\pi^m(\theta_l)}{[(1-\mu\rho)n-(1-\mu)]\pi^m(\theta_l)-n(1-\rho)\mu\rho f_l}\end{aligned}$$

Threshold discount factor for each intermittent strategy increases in level of its fine.

For lower discount factor no price higher than the marginal cost is sustainable for each strategy (proof in Appendix 7.1). We reach the same result as in Bertrand competition with homogeneous product and constant demand function. If the monopoly price is not sustainable then nor is price higher than marginal cost.

## 5.2 Strategy choice

We derive equilibrium collusive choices, considering fixed level of fines. We assume that firms choose their collusive strategy before knowing the first value of  $\theta$ .

If  $\delta$  is sufficiently high then relevant comparisons are:

$$\begin{aligned}\Pi^H &\geq \Pi^C \Leftrightarrow \frac{(1-\mu)\delta\rho}{1-\delta+(1-\mu)\delta\rho}\left(\frac{\pi^m(\theta_h)}{n} - \rho f_h\right) \geq \frac{\pi^m(\theta_l)}{n} - \rho f_l \\ \Pi^C &\geq \Pi^L \Leftrightarrow \frac{1-\delta+\mu\delta\rho}{\mu\delta\rho}\left(\frac{\pi^m(\theta_h)}{n} - \rho f_h\right) \geq \frac{\pi^m(\theta_l)}{n} - \rho f_l \\ \Pi^H &\geq \Pi^L \Leftrightarrow \frac{1-\mu}{\mu}\frac{1-\delta+\mu\delta\rho}{1-\delta+(1-\mu)\delta\rho}\left(\frac{\pi^m(\theta_h)}{n} - \rho f_h\right) \geq \frac{\pi^m(\theta_l)}{n} - \rho f_l\end{aligned}$$

The following conditions  $\Pi^C \geq \Pi^L$ ,  $\Pi^H \geq \Pi^L$  and  $\Pi^H \geq \Pi^C$  are more easily checked if  $f_l$  is high,  $f_h$  is low,  $\mu$  is low,  $\pi^m(\theta_h)$  is high and  $\pi^m(\theta_l)$  is low.

We now turn to lower values of  $\delta$ . In such cases the C strategy may not be sustainable and firms can implement the  $C^*$  strategy. Note that  $\Pi^C \geq \Pi^{C^*}$ . We can make comparisons between  $\Pi^{C^*}$  with  $\Pi^H$  and  $\Pi^L$ , but the first comparison is useless since  $\delta^H \geq \delta_h^C \Leftrightarrow \Pi^C \geq \Pi^H$ .<sup>21</sup> Then in the area where H is sustainable but not C, firms favor H over  $C^*$  since  $\Pi^H \geq \Pi^C \geq \Pi^{C^*}$ .

<sup>21</sup>Proof in Appendix 7.2.

Concerning the other comparison between  $\Pi^{C^*}$  and  $\Pi^L$  we can prove that<sup>22</sup>  $\delta^L \geq \delta_l^C$  iff  $\Pi^C \geq \Pi^L$  and  $\delta^L \leq \delta_l^C \leq \delta_h^C$  if  $\Pi^L \geq \Pi^C$ . For the case  $\Pi^L \geq \Pi^C$  there are parameters values for which firms must choose between L and C\* but the following inequality applies:  $\Pi^L \geq \Pi^C \geq \Pi^{C^*}$  and they select the L strategy. Moreover for these values if L is not sustainable, neither is C\*. Concerning the other case  $\Pi^C \geq \Pi^L$  there may be parameters values for which C can not be sustain whereas L and C\* are sustainable. In such cases we obtain the following condition:

$$\Pi^{C^*} \geq \Pi^L \Leftrightarrow \frac{1 - \delta + \mu\delta\rho}{\mu\delta\rho} \left[ \frac{\pi^*}{n} - \rho f_h \right] \geq \frac{\pi^m(\theta_l)}{n} - \rho f_l$$

### 5.3 Equilibria

We focus on high values of  $\delta$ . The following proposition establishes the equilibrium strategy of colluding firms.

**Proposition 4** *If  $\Pi^H \geq \Pi^C$  and  $\delta > \delta^H$  firms opt for the H strategy. If  $\Pi^C < \Pi^L$  and  $\delta > \delta^L$  they choose the L strategy. If  $\Pi^H < \Pi^C$ ,  $\Pi^C \geq \Pi^L$  and  $\delta > \delta_h^C$  they adopt the C strategy.*

**Proof.** First observe that:

$$\frac{(1 - \mu)\delta\rho}{1 - \delta + (1 - \mu)\delta\rho} < 1 < \frac{1 - \delta + \mu\delta\rho}{\mu\delta\rho}$$

Then,  $\Pi^H \geq \Pi^C \Rightarrow \Pi^C \geq \Pi^L$  and firms choose the H strategy.

Second the following inequality applies:

$$\frac{1 - \mu}{\mu} \frac{1 - \delta + \mu\delta\rho}{1 - \delta + (1 - \mu)\delta\rho} \leq \frac{1 - \delta + \mu\delta\rho}{\mu\delta\rho} \Leftrightarrow 0 \leq 1 - \delta$$

Then  $\Pi^L > \Pi^C \Rightarrow \Pi^L > \Pi^H$  and firms choose the L strategy. ■

Firms choose the H strategy if collusive profits are significantly higher when demand is high. This occurs when  $\pi^m(\theta_h)$  is well above  $\pi^m(\theta_l)$ ,  $f_h$  is not too large compared to  $f_l$  or if  $\mu$  is not too high. Although collusion may be sustainable if demand is low firms do not implement it and stay undetectable. In this case they can not be fined and collusive agreement is not dissolved. In terms of expectation, firms collude during  $1/\rho$  periods before cartel is detected and dissolved and they choose to collude only if demand is high. We get a different result to RS but we do not consider the same range of values for  $\delta$ .

**Corollary 5** *When firms choose the H strategy, cartel leads to an increase in price more important when demand is high.*

This result can be reversed if  $f_h$  is hugely higher than  $f_l$ <sup>23</sup> in which case firms favor collusion if demand is low and otherwise break off the cartel (L strategy). Then we reach counter-cyclical price as in RS.

<sup>22</sup>Proof in Appendix 7.2.

<sup>23</sup>If  $f_h = f_l$  then the following inequality applies:  $\Pi^C \geq \Pi^L$  since  $\frac{1 - \delta + \mu\delta\rho}{\mu\delta\rho} > 1$ . In such case the L strategy is not an equilibrium one.

In other cases, firms choose the C strategy: collusion is sustainable regardless of demand but is more difficult to sustain during booms.

In section 5.5 we illustrate these results with the following demand function:  $Q(p, \theta) = \theta(A - p)$ . Before that, we rank collusive strategies according to consumers surplus and global welfare.

## 5.4 Consumer surplus and social welfare

Ranking of consumer surplus and social welfare is not obvious. Price effect as well as length of cartel play an important role and impact on strategies differently (for instance, if demand is low, firms compete if they play the H strategy then consumer surplus should be higher compared to the C strategy but, overall, cartel is not the same length).

We still focus on sufficiently high values of  $\delta$  to ensure that all collusive strategies can be applied.

Expected consumer surplus following cartel dissolution is:<sup>24</sup>

$$CS = \sum_{t=0}^{\infty} \delta^t [\mu cs^{nc}(\theta_t) + (1 - \mu) cs^{nc}(\theta_h)] = \frac{1}{1 - \delta} [\mu cs^{nc}(\theta_t) + (1 - \mu) cs^{nc}(\theta_h)]$$

We then deduce expected consumer surplus relative to the various strategies:

$$CS^i = \begin{cases} \frac{\mu cs^m(\theta_t) + (1 - \mu) cs^m(\theta_h) + \delta \rho CS}{1 - \delta(1 - \rho)} & \text{for } i = C \text{ strategy} \\ \frac{\mu cs^{nc}(\theta_t) + (1 - \mu) cs^m(\theta_h) + (1 - \mu) \delta \rho CS}{1 - \delta + (1 - \mu) \delta \rho} & \text{for } i = H \text{ strategy} \\ \frac{\mu cs^m(\theta_t) + (1 - \mu) cs^{nc}(\theta_h) + \mu \delta \rho CS}{1 - \delta + \mu \delta \rho} & \text{for } i = L \text{ strategy} \end{cases}$$

**Proof.** See Appendix 7.3 ■

Social welfare is composed of consumers' surplus, producers' surplus and antitrust fines (the fine transfer is welfare neutral). We accordingly have:

$$W^i = \begin{cases} \frac{\mu[cs^m(\theta_t) + \pi^m(\theta_t)] + (1 - \mu)[cs^m(\theta_h) + \pi^m(\theta_h)] + \delta \rho CS}{1 - \delta(1 - \rho)} & \text{for } i = C \text{ strategy} \\ \frac{\mu cs^{nc}(\theta_t) + (1 - \mu)[cs^m(\theta_h) + \pi^m(\theta_h)] + (1 - \mu) \delta \rho CS}{1 - \delta + (1 - \mu) \delta \rho} & \text{for } i = H \text{ strategy} \\ \frac{\mu[cs^m(\theta_t) + \pi^m(\theta_t)] + (1 - \mu) cs^{nc}(\theta_h) + \mu \delta \rho CS}{1 - \delta + \mu \delta \rho} & \text{for } i = L \text{ strategy} \end{cases}$$

Solving comparison of consumer surplus yields the following inequalities, where  $\Delta cs(\theta_i) = cs^{nc}(\theta_i) - cs^m(\theta_i)$ :

$$\begin{aligned} CS^H &\geq CS^C \Leftrightarrow \Delta cs(\theta_t) \geq \frac{(1 - \mu) \delta \rho}{1 - \delta + (1 - \mu) \delta \rho} \Delta cs(\theta_h) \\ CS^C &\geq CS^L \Leftrightarrow \Delta cs(\theta_t) \geq \frac{1 - \delta + \delta \rho \mu}{\delta \rho \mu} \Delta cs(\theta_h) \\ CS^H &\geq CS^L \Leftrightarrow \Delta cs(\theta_t) \geq \frac{1 - \mu}{\mu} \frac{1 - \delta + \mu \delta \rho}{1 - \delta + (1 - \mu) \delta \rho} \Delta cs(\theta_h) \end{aligned}$$

<sup>24</sup>As with previous notations  $cs(\theta)$  denotes the period surplus and  $CS(\theta)$  the discounted surplus. Remind that superscript  $nc$  designates the non cooperative situation.



We then deduce the following comparisons for welfare:

$$\begin{aligned}
W^H &\geq W^C \Leftrightarrow \Delta cs(\theta_l) - \pi^m(\theta_l) \geq \frac{(1-\mu)\delta\rho}{1-\delta+(1-\mu)\delta\rho}(\Delta cs(\theta_h) - \pi^m(\theta_h)) \\
W^C &\geq W^L \Leftrightarrow \Delta cs(\theta_l) - \pi^m(\theta_l) \geq \frac{1-\delta+\delta\rho\mu}{\delta\rho\mu}(\Delta cs(\theta_h) - \pi^m(\theta_h)) \\
W^H &\geq W^L \Leftrightarrow \Delta cs(\theta_l) - \pi^m(\theta_l) \geq \frac{1-\mu}{\mu} \frac{1-\delta+\mu\delta\rho}{1-\delta+(1-\mu)\delta\rho}(\Delta cs(\theta_h) - \pi^m(\theta_h))
\end{aligned}$$

The first point emerging from these computations is that ranking of surplus depends on parameters values. The H strategy seems to be less harmful than the C strategy since it is limited to only one state of demand. However, the H strategy is expected to be detected latter. Then this collusive strategy does not impact consumers when demand is low but consumers are expected to suffer from collusion for a longer time when demand is high. The most damaging collusive strategy for consumers and global welfare depends on parameters values.

The second point is that these comparisons are different from borderlines defining firms' choice. Equilibrium firms' strategies diverge from socially optimal choices, which is to be expected since firms can make collusive agreements. The choice of equilibrium collusive strategies depends on expected fines, this is not the case for consumer surplus and social welfare. Then antitrust fines can be used to impact the choice of the collusive strategy adopted and to reduce gravity of offense. We deal with these points in the subsection 5.6.

## 5.5 Illustration with a specific demand function

In order to graphically illustrate the previous results and achieve further outcomes we consider the following specific demand function:  $Q(p, \theta) = \theta(A - p)$ . We derive price, quantity and profits compatible with monopoly equilibrium:

$$p^m = \frac{A+c}{2}, \quad Q^m(\theta) = \theta \left( \frac{A-c}{2} \right) \quad \text{and} \quad \pi^m(\theta) = \theta \frac{(A-c)^2}{4}$$

Monopoly price does not depend on  $\theta$  according to the specified demand function.

Expressions of consumer surplus are:

$$cs^{nc}(\theta) = \frac{1}{2}\theta(A-c)^2 \quad \text{and} \quad cs^m(\theta) = \frac{\theta}{8}(A-c)^2$$

then:

$$cs^m(\theta) - cs^{nc}(\theta) = -\frac{3}{8}\theta(A-c)^2$$

High value of  $\theta$  amplifies the negative impact of cartel then collusion is more harmful if demand is high.<sup>25</sup> Moreover, relative to perfect competition, the consumer loss from monopoly situation is always higher than firms' gain, then variations in social welfare and consumer surplus are perfectly lined up.

<sup>25</sup>We could obtain opposite result in looking at income effect that could lead to higher marginal willingness to pay for low demand. In this article we consider partial equilibrium, we ignore income effect then consumer surplus is strictly measured as the area below the downward-sloping demand curve.

Comparisons to collusive profits lead to following results:

$$\begin{aligned}\Pi^H &\geq \Pi^C \Leftrightarrow \theta_h \geq \theta_I \equiv \frac{1-\delta+(1-\mu)\delta\rho}{(1-\mu)\delta\rho} \left( \theta_l - 4n\rho \frac{f_l}{(A-c)^2} \right) + 4n\rho \frac{f_h}{(A-c)^2} \\ \Pi^C &\geq \Pi^L \Leftrightarrow \theta_h \geq \theta_{II} \equiv \frac{\mu\delta\rho}{1-\delta+\mu\delta\rho} \left[ \theta_l - 4n\rho \frac{f_l}{(A-c)^2} \right] + 4n\rho \frac{f_h}{(A-c)^2} \\ \Pi^H &\geq \Pi^L \Leftrightarrow \theta_h \geq \theta_{III} \equiv \frac{\mu}{1-\mu} \frac{1-\delta+(1-\mu)\delta\rho}{1-\delta+\mu\delta\rho} \left[ \theta_l - 4n\rho \frac{f_l}{(A-c)^2} \right] + 4n\rho \frac{f_h}{(A-c)^2}\end{aligned}$$

In the  $(\theta_l, \theta_h)$  plane, each borderline defined by  $\theta_I$ ,  $\theta_{II}$  and  $\theta_{III}$  is linear function and moves upward [downward] by parallel translation with increased value of  $f_h$  [ $f_l$ ].

Comparisons of consumer surplus and social welfare are given by:

$$\begin{aligned}CS^H &\geq CS^C \Leftrightarrow W^H \geq W^C \Leftrightarrow \theta_h \leq \theta_{IV} \equiv \frac{1-\delta+(1-\mu)\delta\rho}{(1-\mu)\delta\rho} \theta_l \\ CS^C &\geq CS^L \Leftrightarrow W^C \geq W^L \Leftrightarrow \theta_h \leq \theta_V \equiv \frac{\delta\rho\mu}{1-\delta+\delta\rho\mu} \theta_l \\ CS^H &\geq CS^L \Leftrightarrow W^H \geq W^L \Leftrightarrow \theta_h \leq \theta_{VI} \equiv \frac{1-\delta+(1-\mu)\delta\rho}{1-\delta+\mu\delta\rho} \frac{\mu}{1-\mu} \theta_l\end{aligned}$$

The next graphical representations (figures 1 to 4) illustrate equilibrium strategies and consumer surplus ranking for different parameters values. Overall we identify six specific zones (each figure does not necessarily contains all areas):

| Zone | Equilibrium strategy | Consumer and social surplus ranking |
|------|----------------------|-------------------------------------|
| 1    | H                    | L > C > H                           |
| 2    | H                    | L > H > C                           |
| 3    | C                    | L > C > H                           |
| 4    | C                    | L > H > C                           |
| 5    | L                    | Irrelevant                          |
| 6    | C*                   | Irrelevant                          |

Since  $\frac{\delta\rho\mu}{1-\delta+\delta\rho\mu} < 1$  then  $W^L > W^C$ . Moreover  $W^H < W^L$  if  $\mu < 1/2$ .

One of the main issues of this article is whether  $f_l < f_h$  must be implemented by antitrust authority. We start look at  $f_l = f_h$  and then relax this.

If  $f_l = f_h$  then  $\Pi^C \geq \Pi^L$ . Graphical representation in  $(\theta_l, \theta_h)$  plane is straightforward. Firms choose the H strategy if  $\theta_h$  is high and C strategy if  $\theta_h$  and  $\theta_l$  have similar values.  $\delta^H$  only depends on  $\theta_h$ , then the threshold is a minimal value  $\underline{\theta}_h^H$  defining an horizontal straight line.<sup>26</sup> In the same way  $\delta_h^C$  and  $\delta_l^C$  are horizontal straight line corresponding to the minimal values  $\underline{\theta}_h^C$  and  $\underline{\theta}_l^C$ .<sup>27</sup>  $\delta^L$  is a vertical straight line corresponding to the minimal value  $\underline{\theta}_l^L$ .<sup>28</sup> If  $f_h = f_l$  this latter threshold is irrelevant since firms never choose the L strategy.

<sup>26</sup>The expression of  $\underline{\theta}_h^H$  is:  $\frac{\delta(1-\rho)(1-\mu)}{\delta[n(1-\rho+\mu\rho)-\mu]-n+1} \frac{4n\rho f_h}{(A-c)^2}$ .

<sup>27</sup>With:  $\underline{\theta}_h^C = \frac{\delta(1-\rho)}{n-1-\delta(1-\rho)(n-\mu)} \left[ \mu\theta_l - \mu \frac{4n\rho f_l}{(A-c)^2} - (1-\mu) \frac{4n\rho f_h}{(A-c)^2} \right]$ ;  $\underline{\theta}_l^C = \frac{[n-1-\delta(1-\rho)(\mu+n-1)]\theta_l + \delta(1-\rho) \frac{4n\rho}{(A-c)^2} [\mu f_l + (1-\mu)f_h]}{\delta(1-\rho)(1-\mu)}$ .

<sup>28</sup>The expression of  $\underline{\theta}_l^L$  is:  $\frac{\delta(1-\rho)\mu}{\delta[(1-\mu\rho)n-(1-\mu)]-n+1} \frac{4n\rho f_l}{(A-c)^2}$ .

Border lines set by the comparison of consumer surplus (or social surplus) are also straight lines. If the fines are nil these border lines are exactly the same than the ones computed by profit comparisons: firms' choices are diametrically opposed to welfare maximisation.

If  $f_h = f_l > 0$  the borderline  $\theta_I$  is below  $\theta_{IV}$  since  $\frac{1-\delta+(1-\mu)\delta\rho}{(1-\mu)\delta\rho} > 1$  and for the same level of fine, the scale of downward move driven by  $f_l$  is larger than the upward shift induced by  $f_h$ . As a result, there is an area where firms choose the socially optimal H strategy.

Figure 1 helps to illustrate some of the previous results if  $f_h = f_l = 2000$ ;  $\mu = 0.2$ ;  $\rho = 0.01$ ;  $\delta = 0.95$ ;  $n = 5$  and  $A - c = 10$ .

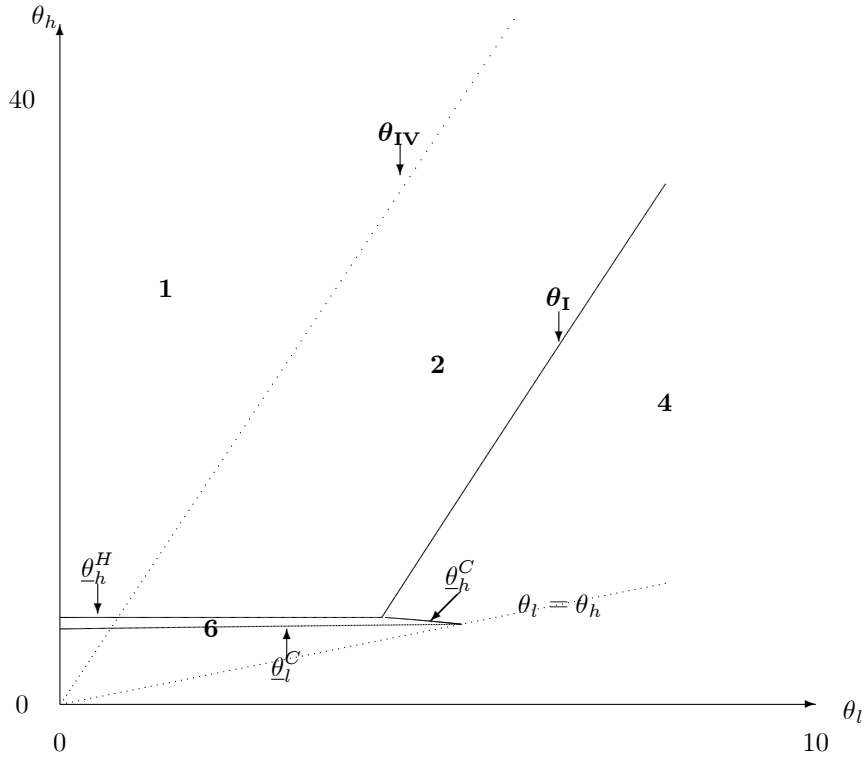


Figure 1: Equilibrium strategies and consumer surplus ranking if  $f_h = f_l$

Full border lines delimit equilibrium strategies and border lines ranking consumer surplus are plotted with dots (the diagonal line is also depicted since  $\theta_h \geq \theta_l$ ).

In this figure the L strategy is never sustainable<sup>29</sup> then we can easily define the area where firms play the C\* strategy: at the left of the borderline  $\theta_I$  if  $\delta_l^C < \delta < \delta^H$  and at the right if  $\delta_l^C < \delta < \delta_h^C$ .

For lower values of  $f_h$  the borderline  $\theta_I$  moves downward but the borderlines  $\theta_{IV}$ ,  $\theta_V$  and  $\theta_{VI}$  are unchanged since they do not depend of  $f_h$ . Then the scenario  $f_l > f_h \geq 0$  generates similar graphical representation to the previous one.

<sup>29</sup>We assume that  $\mu = 0.2$  then low demand occurs on average every five periods and expected discount factor used to value the collusive L strategy is  $\delta^5 \simeq 0.77$ . However in the basic model of price competition with homogeneous product, cartel between 5 firms is sustainable if  $\delta \geq 0.8$ . Therefore even if  $\rho = 0$  the L strategy is not sustainable if  $\delta = 0.95$ ,  $\mu = 0.2$  and  $n = 5$ .

For lower values of  $f_l$  the borderline  $\theta_I$  moves upward and may be over  $\theta_{IV}$ . The zone 2 (strategy choice is H and  $W^H > W^C$ ) disappears and the zone 3 emerges: strategy choice is C and  $W^C > W^H$ . Figure 2 illustrates the results obtained in such cases. We consider these parameters values:<sup>30</sup>  $\mu = 0.8$ ;  $\rho = 0.01$ ;  $\delta = 0.97$ ;  $n = 5$ ;  $A - c = 10$ ;  $f_h = 2000$ ;  $f_l = 0$ .

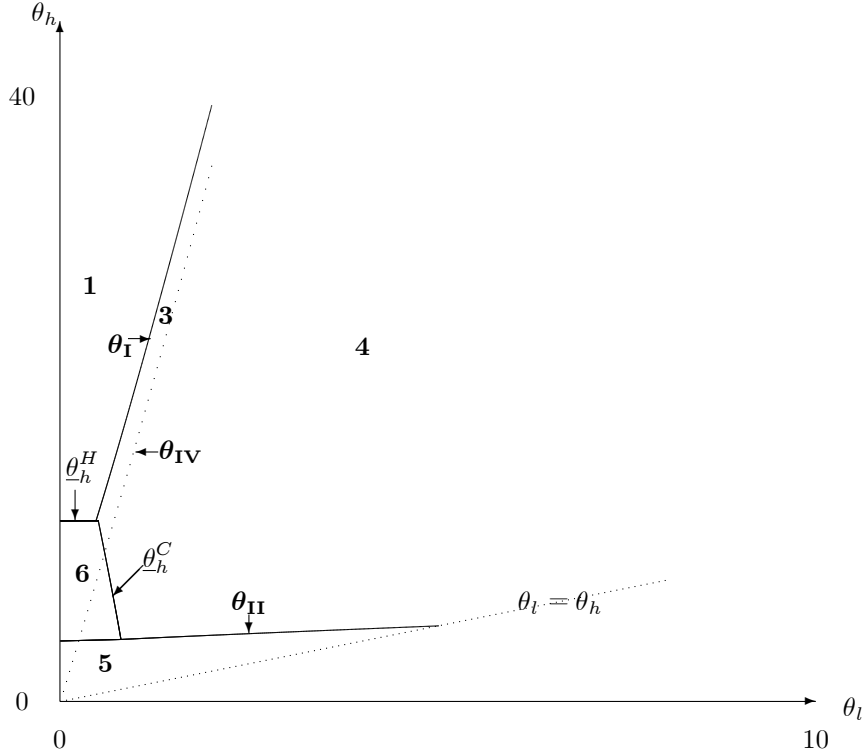


Figure 2: Equilibrium strategies and consumer surplus ranking if  $f_h > f_l$

Henceforward the L strategy is always sustainable ( $\delta$  is high and  $f_l = 0$ ). If  $\Pi^L > \Pi^C$  then  $\Pi^L > \Pi^{C^*}$ . If  $\Pi^L < \Pi^C$  and whenever the C strategy is no longer sustainable then the C\* strategy can be sustained ( $\theta_I^C$  is below  $\theta_{II}$ ) and is selected over L.<sup>31</sup>

The previous graphs based on a specific demand function support that intermittent collusive strategies H and L can be equilibrium choices. They will be used in the next section's discussion.

## 5.6 Level of fines

We now analyze the optimal level of fines. First we state results without specifying a demand function then we use the previous one which leads to more specific conclusions.

<sup>30</sup> For L to be an equilibrium strategy we must assume  $f_l < f_h$ , but also modify some other parameters values. We strongly increase  $\mu$  and we set  $f_l = 0$ .  $\delta$  is also increased to ensure that H is sustainable.

<sup>31</sup> Comparison of profits leads to the following result (see Appendix 7.4):

$$\Pi^{C^*} \geq \Pi^L \Leftrightarrow \theta_l \geq \frac{4n\rho}{(A-c)^2} \left[ \frac{[1-\delta(1-\rho)](1-\delta+\mu\delta\rho)(n-1)}{[(1-\delta+\delta\rho n)(1-\rho)-(n-1)\rho]\delta\mu} f_h + f_l \right]$$

**Fines impacts:** Under assumption A2, fines  $f_h$  and  $f_l$  may have three effects. (1) First they shift the collusive sustainability thresholds (deterrence effect). (2) Moreover they affect collusive price  $p^*$  during booms under the C\* strategy (collusive price effect). (3) Lastly they can modify the choice of collusive strategy (marginal deterrence effect).

The deterrence effect (1) leads the antitrust authority to apply maximum fines.

**Proposition 6** *Higher level of fine  $f_h$  [ $f_l$ ] increases values of  $\delta_l^C$ ,  $\delta_h^C$  and  $\delta^H$  [ $\delta_l^C$ ,  $\delta_h^C$  and  $\delta^L$ ].*

All collusive strategies are more difficult to sustain for higher fines.

The collusive price effect (2) has a similar impact. Higher fines reduce  $\pi^*$  and constrain firms to decrease collusive prices during booms under the C\* strategy.

Implications of the marginal deterrence effect (3) are obvious for collusive choice but are more ambiguous as regards the optimal fine level.

**Proposition 7** *Higher level of  $f_h$  or/and lower level of  $f_l$  results in a switch of the borderlines  $\theta_I$  and  $\theta_{II}$  upward: firms may switch from the H to the C strategy or from the C to the L strategy.*

**Implications for optimal level of fines:** Under assumption A1 optimal antitrust policy was to set the highest achievable fines to maximize the deterrence and the collusive price effects.

Under assumption A2 firms may adopt different collusive strategies. Fines have a deterrent effect and may change collusive strategy. The latter is somewhat parallel to marginal deterrence in some works dealing with crime. Lower value of fine can modify collusive strategy and be welfare increasing. Here we consider a more complex than traditional model of marginal deterrence because the ranking of infringements according to the damages caused to the third party depends on the parameters values. The C strategy seems to be more harmful than the H strategy as collusion occurs at every state of demand but, depending on parameters values, the damaging effects on welfare may be stronger with the H strategy (since detection occurs later).

Without specifying demand function and density function for  $\theta_l$  and  $\theta_h$ , only overall result can be obtained.

**Proposition 8** *Under assumption A2, the highest level of fines might not always be optimal.*

The ranking of infringements depends on parameters values (especially on  $\theta_l$  and  $\theta_h$ ) it is therefore not possible to decide which one of the two fines should be below the highest achievable fine. Nevertheless the following corollary can be stated:

**Corollary 9** *It may sometimes be optimal to set  $f_l < f_h$ .*

So reducing fines during recessions can sometimes increase both consumer surplus and social welfare. This result is mainly based on the marginal deterrence effect. Decreasing  $f_l$  may induce firms to switch from

the H to the C strategy. Antitrust authorities wish that collusive firms still maintain higher prices during recessions because on the one hand collusive impact on consumer surplus is lower than during high demand period and on the other hand antitrust authorities can more easily detect and break off cartels. Lower level of fine  $f_l$  may also induce other cartels to switch from the C to the L strategy: in such cases collusion is only active during low demand period and is less harmful for consumers, cartels are expected to be dissolved latter but are less harmful when they are active.

Setting  $f_l < F$  is optimal if there is sufficiently high density of firms where marginal deterrence effect exists and, on the contrary, sufficiently low density of firms where lower level of fine  $f_l$  decreases deterrence effect and where firms choose the C strategy.

We illustrate these results with the previously used specific demand function (section 5.5).

**Specific demand function** Multi-effect of fines makes it difficult to determine their optimal level, thereafter we concentrate on the marginal deterrence effect (3). We assume that:  $\delta \geq \min(\delta_h^C, \delta_h^H)$ . We use the same values as in figure 1. L is never sustainable and fines only impact the borderline  $\theta_I$ . We set  $F_l = F_h = 2000$ : the first graphical representation shows the case in which  $f_l = f_h = F$  and this is clearly not the optimal policy.

Lower level of  $f_h$  moves the borderline  $\theta_I$  downward. In this case firms may switch from the C strategy to the H one, this is socially optimal since  $W^H > W^C$  in this area. If  $\delta \geq \min(\delta_h^C, \delta_h^H)$  and  $f_l > f_h$  then the antitrust authority must set:  $f_h = 0$  and  $f_l = F$ . Figure 3 illustrates the previous results<sup>32</sup> for  $\mu = 0.2$ ;  $\rho = 0.01$ ;  $\delta = 0.95$ ;  $n = 5$ ;  $A - c = 10$ ;  $f_h = 0$ ;  $f_l = 2000$ .

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<sup>32</sup>  $f_h = 0$  implies that H is always sustainable and C is sustainable at the right of the borderline  $\theta_I$ .

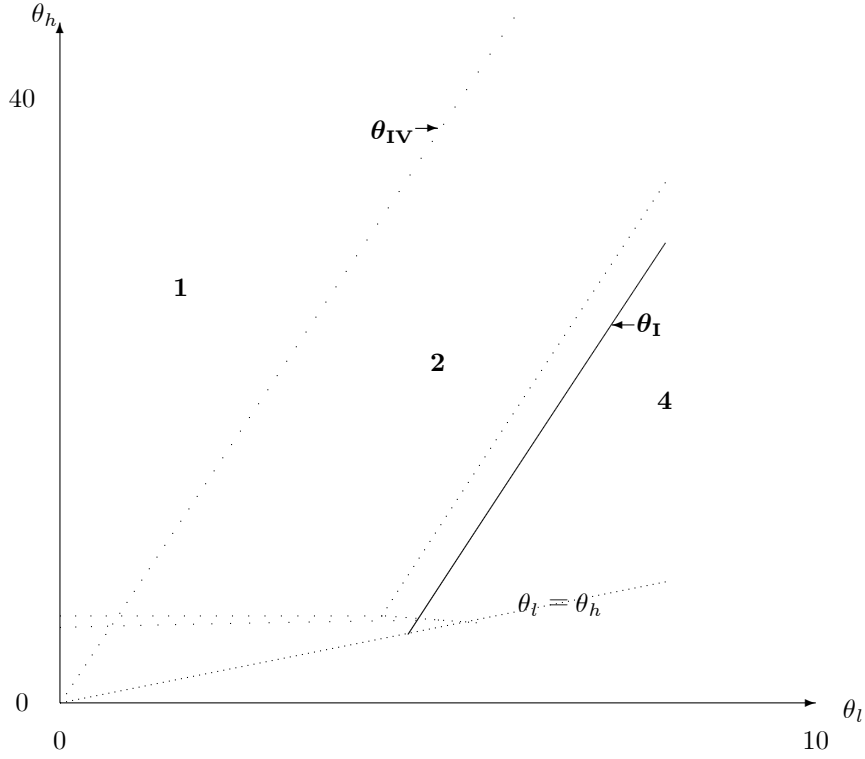


Figure 3: Equilibrium strategies and consumer surplus ranking if  $f_l > f_h = 0$

Borderlines in Figure 1 are plotted with dots, the shifted borderline  $\theta_I$  is plotted with full line.

Starting from  $f_l = f_h = F$ , lower value of  $f_l$  while maintaining  $f_h$  unchanged can also be considered. Consumer surplus and social welfare decrease in a slight reduction of  $f_l$ . The borderline  $\theta_I$  moves to the left then firms may switch from the strategy H to the C strategy but it is not socially optimal. But the impact of  $f_l$  on global welfare is a non-monotonic one. As long as  $\theta_I$  is on the right side of  $\theta_{IV}$ , lower value of  $f_l$  decreases social welfare. In the opposite case, firms can switch from H to the socially optimal C strategy. This option is strengthened by a decreasing value of  $f_l$ . If antitrust authority decides to decrease  $f_l$  then it should set  $f_l = 0$  and maintain  $f_h = F$ . Figure 4 illustrates the previous results<sup>33</sup> for  $\mu = 0.2$ ;  $\rho = 0.01$ ;  $\delta = 0.95$ ;  $n = 5$ ;  $A - c = 10$ ;  $f_h = 2000$ ;  $f_l = 0$ .

<sup>33</sup> $\theta_h^H$  remains unchanged. The borderline  $\theta_I$  moves upward and is above  $\theta_{IV}$ .

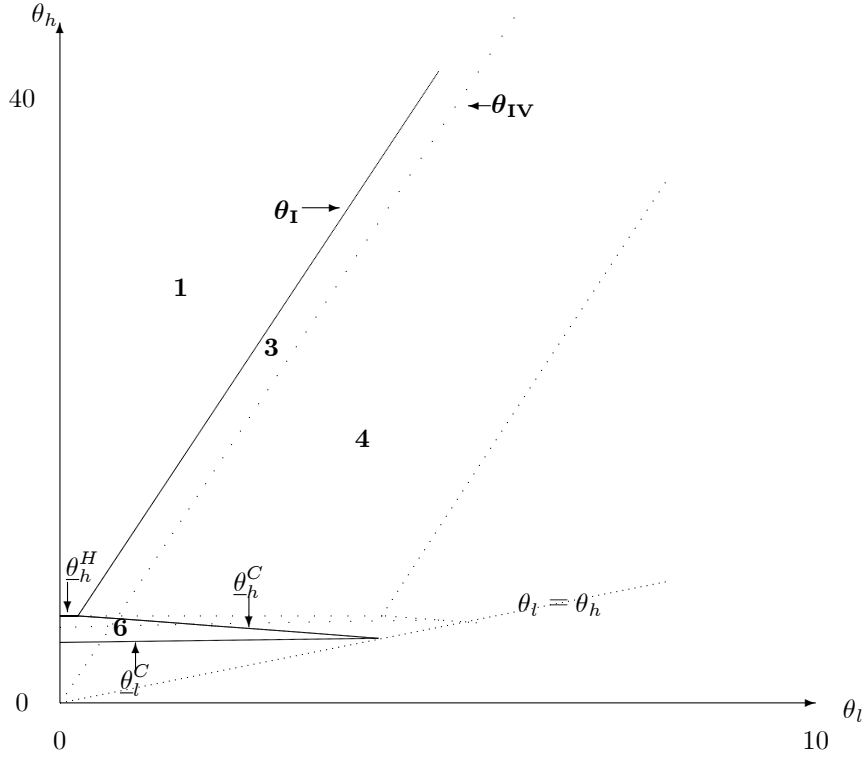


Figure 4: Equilibrium strategies and consumer surplus ranking if  $f_h > f_l = 0$

If  $f_h = f_l = 0$  then firms' choices result to be the worst welfare situations. Then antitrust authority should move away as much as possible the borderline specifying the firms' strategy and the one which ranks consumer or social surplus. The borderline  $\theta_I$  can be moved to the left by setting  $f_h = F$  and  $f_l = 0$  or right by fixing the opposite. The optimal levels of fine will either be  $f_h = F$  and  $f_l = 0$  or  $f_h = 0$  and  $f_l = F$ . The choice between these two opposing options depends on relative weight of industries below or above the borderline  $\theta_{IV}$ .

With the first option  $f_h = F$  and  $f_l = 0$  it is not optimal to fine cartel during recessions (even if the antitrust authority still actively engages in detection in order to dissolve the cartel). This reflects the marginal deterrence effect (firms may switch from the H strategy to the C strategy), not the consideration of potential risk of bankruptcy due to low demand. Collusion during low demand period decreases consumer surplus but this is offset by shorter collusion under the C strategy.

**Lower values of  $\delta$ :** In this case effects (1) and (2) should also be considered. In Figure 3 lower value of  $f_h$  decreases  $\delta^H$  and moves  $\theta_h^H$  downward. Then firms may switch from the C\* strategy to the strategy H generating an ambiguous effect on social welfare. Moreover there is an area where firms switch from no collusion to the strategy H leading to falling consumer surplus. In Figure 4 lower value of  $f_l$  decreases  $\delta_h^C$  and  $\delta_l^C$ . Some firms switch from the C\* strategy to the C strategy and other switch from no collusion to the C or C\* strategies: consumer surplus is reduced.



Once again setting one maximum fine ( $f_l$  or  $f_h$ ) is optimal. Antitrust authority faces a tradeoff as regards the other fine: effects 1 and 2 encourage increased fine but effect 3 favors the opposite. For some parameters values a lower fine  $f_l$  remains optimal in which case the number of active cartels increases but the gravity and the duration of some infringements decrease.

If the L strategy can be an equilibrium then the situation is far more complicated. If antitrust authority previously focused on lower  $f_l$  then this policy is now reinforced. By contrast if optimal policy was to set lower fine  $f_h$  then accounting for the L strategy provides an incentive to decrease  $f_l$  and increase  $f_h$ .

## 6 Conclusion

In this article we explore firms behavior and cartel enforcement when colluding firms face random demand fluctuations.

If a cartel is detectable irrespective of the collusive price (assumption A1) then we obtain similar results as RS without antitrust policy. Particularly, collusive agreements are less stable in booms than in recessions and prices can be counter-cyclical. In contrast, if for any period during which collusive firms set competitive price the probability detection is zero (assumption A2), then firms may implement intermittent collusive strategy. Firms set monopoly price only during periods where collusion is the most profitable strategy and charge marginal cost otherwise. Antitrust authority is active then cartels do not last forever and firms can not collude again if cartels are dissolved. Then firms prefer to avoid the risk of cartel detection for any period in which collusion is less worthwhile. Collusive prices are procyclical if firms play the strategy H. Firms set monopoly price only during booms and charge marginal cost if demand is low. By contrast they charge countercyclical collusive prices if they play the L strategy. Finally if collusive profits are relatively similar for both demand states then firms collude once the cartel is dissolved and cartel prices are weakly<sup>34</sup> procyclical if  $\delta$  is high (C strategy) and countercyclical for lower values of  $\delta$  (C\* strategy).

Then we address cartel enforcement and level of fines. Under Assumption A1, antitrust authorities aim to deter collusive agreements or at least minimize their negative impact. This requires to set the highest achievable fines. Under assumption A2 fines may also change collusive strategy and setting one maximum fine is optimal. The other fine level reflects a tradeoff between deterrence effect and incentive effect driving colluding firms to choose a less harmful strategy. Then optimal level of fines may depend on the demand state. Reducing fines if demand is low can support the marginal deterrence effect, this is not related to the potential risk of bankruptcy (not included in this model). Perhaps less intuitively, antitrust authority may instead reduce fines during booms in order firms switch from the C strategy to the strategy H so that they do not collude during recessions.

This theoretical article suggests that setting maximum fines regardless of demand is not necessarily optimal. Depending on the demand state, lower fines can change collusive behavior and lead to less harmful

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<sup>34</sup>In the example case used in this article collusive prices are constant since they do not depend on demand. For a more general demand function these prices will generally be procyclical.

strategy. Designing the optimal fines in antitrust infringements is complex and requires a significant knowledge of the distribution of industries according to the parameters values. Without such information, maximal fine regardless of demand fluctuation is potentially a second-best optimum.

In this article we have exclusively focused on the level of fines to fight cartel facing demand fluctuations. But antitrust authority may also adapt detection efforts to economic situation and we plan to include leniency programs for future research. We also intend to address the role of financial situation of firms. Reducing fines during recessions may help firms to fight bankruptcy and invest even during reduced availability of financing caused by economic crisis. However, in this article, we demonstrate that financial trouble is not the only possible justification for lower fines during recessions.

## 7 Appendix

### 7.1 Non-sustainability of the intermittent collusive strategies for intermediate values of $\delta$

**H strategy (collusion during booms):** Firms charge the marginal cost if demand is low. During booms firms set a price  $p^* \in ]c, p^m[$  and the profit is:  $\frac{\pi^*}{n}$ . Firms have incentives to deviate only during booms. Collusion is sustainable iff:

$$\frac{\pi^*}{n} - \rho f_h + \delta(1 - \rho)\Pi^* \geq \pi^* - \rho f_h + \delta \times 0$$

We need to determine  $\Pi^*$  :

$$\Pi^* = \mu[0 + \delta\Pi^*] + (1 - \mu) \left[ \frac{\pi^*}{n} - \rho f_h + \delta(1 - \rho)\Pi^* \right] \Leftrightarrow \Pi^* = \frac{1 - \mu}{1 - \delta + (1 - \mu)\delta\rho} \left[ \frac{\pi^*}{n} - \rho f_h \right]$$

Replacing for  $\Pi^*$  in the previous condition allows us to re-write the no-deviation condition during booms as:

$$\begin{aligned} \frac{\pi^*}{n} - \rho f_h + \delta(1 - \rho) \frac{1 - \mu}{1 - \delta + (1 - \mu)\delta\rho} \left[ \frac{\pi^*}{n} - \rho f_h \right] &\geq n \frac{\pi^*}{n} - \rho f_h \\ \Leftrightarrow \delta &\geq \delta^{H*} \equiv \frac{(n - 1)}{[n(1 - \rho + \mu\rho) - \mu] - n(1 - \rho)(1 - \mu)\rho \frac{f_h}{\pi^*}} \end{aligned}$$

$\frac{f_h}{\pi^*}$  decreases in  $\pi^*$ . Then  $[n(1 - \rho + \mu\rho) - \mu] - n(1 - \rho)(1 - \mu)\rho \frac{f_h}{\pi^*}$  increases and  $\delta^{H*}$  decreases in  $\pi^*$ . The minimum value of  $\delta^{H*}$  is reached for  $p^* = p^m$ .

Then the H strategy is easier to sustain when firms set the monopoly price than a lower price.

If  $\delta < \delta^H$  the H strategy is not sustainable.

**L strategy (collusion during recessions):** Firms charge the marginal cost if demand is high. During recessions firms set a price  $p^* \in ]c, p^m[$  and the profit is:  $\frac{\pi^*}{n}$ . Firms have incentives to deviate only during recessions. Collusion is sustainable iff:

$$\frac{\pi^*}{n} - \rho f_l + \delta(1-\rho)\Pi^{L^*} \geq \pi^* - \rho f_l + \delta 0 \Leftrightarrow \delta \geq \delta^{L^*} \equiv \frac{(n-1)}{[(1-\mu\rho)n - (1-\mu)] - n(1-\rho)\mu\rho\frac{f_l}{\pi^*}}$$

The minimum value of  $\delta^{L^*}$  is reached for  $p^* = p^m(\theta_l)$ . Then the L strategy is easier to sustain when firms set the monopoly price than a lower price.

If  $\delta < \delta^L$  the L strategy is not sustainable.

## 7.2 Comparison of sustainability thresholds

If demand is high the collusive strategy  $i \in \{C, H\}$  is sustainable iff:

$$\frac{\pi^m(\theta_h)}{n} - \rho f_h + \delta(1-\rho)\Pi^i \geq \pi^m(\theta_h) - \rho f_h$$

Deviation and current collusive profits are the same with the C and H strategies. But the discounted expected collusive profit is different, then the following inequality applies:

$$\delta^H \geq \delta_h^C \Leftrightarrow \Pi^C \geq \Pi^H$$

If demand is low the collusive strategy  $i \in \{C, L\}$  is sustainable iff:

$$\frac{\pi^m(\theta_l)}{n} - \rho f_l + \delta(1-\rho)\Pi^i \geq \pi^m(\theta_l) - \rho f_l$$

From which we deduce:

$$\delta^L \geq \delta_l^C \Leftrightarrow \Pi^C \geq \Pi^L$$

## 7.3 Computations of expected consumer surplus

**C strategy:** Consumer surplus is  $cs^m(\theta_k)$  throughout the collusive period and  $cs^{nc}(\theta_k)$  afterwards,  $k \in \{l, h\}$ .

$$\begin{aligned} CS^C &= \mu cs^m(\theta_l) + (1-\mu)cs^m(\theta_h) + \delta[(1-\rho)CS^C + \rho CS] \\ \Leftrightarrow CS^C &= \frac{\mu cs^m(\theta_l) + (1-\mu)cs^m(\theta_h) + \delta\rho CS}{1 - \delta(1-\rho)} \end{aligned}$$

**H strategy:** Consumer surplus is  $cs^m(\theta_h)$  or  $cs^{nc}(\theta_l)$  throughout the collusive period and  $cs^{nc}(\theta_k)$  afterwards,  $k \in \{l, h\}$ .

$$\begin{aligned} CS^H &= \mu [cs^{nc}(\theta_l) + \delta CS^H] + (1-\mu) \{sc^m(\theta_h) + \delta[(1-\rho)CS^H + \rho CS]\} \\ \Leftrightarrow CS^H &= \frac{\mu cs^{nc}(\theta_l) + (1-\mu)cs^m(\theta_h) + (1-\mu)\delta\rho CS}{1 - \delta + (1-\mu)\delta\rho} \end{aligned}$$

**L strategy:** Consumer surplus is  $sc^{nc}(\theta_h)$  or  $sc^m(\theta_l)$  throughout the collusive period and  $sc^{nc}(\theta_k)$  afterwards,  $k \in \{l, h\}$ .

$$\begin{aligned} CS^L &= \mu \{cs^m(\theta_l) + \delta [(1-\rho)CS^L + \rho CS]\} + (1-\mu) [cs^{nc}(\theta_h) + \delta CS^L] \\ \Leftrightarrow CS^L &= \frac{\mu cs^m(\theta_l) + (1-\mu) cs^{nc}(\theta_h) + \mu\delta\rho CS}{1-\delta + \mu\delta\rho} \end{aligned}$$

#### 7.4 Comparison of $\Pi^L$ and $\Pi^{*C}$

$$\begin{aligned} \Pi^L \geq \Pi^{*C} &\Leftrightarrow \frac{\mu}{1-\delta + \mu\delta\rho} \left[ \frac{\pi^m(\theta_l)}{n} - \rho f_l \right] \geq \frac{\mu \left( \frac{\pi^m(\theta_l)}{n} - \rho f_l \right) + (1-\mu) \left( \frac{\pi^*}{n} - \rho f_h \right)}{1-\delta(1-\rho)} \\ &\Leftrightarrow \frac{1-\delta + \mu\delta\rho}{\mu\delta\rho} \left[ \frac{\pi^*}{n} - \rho f_h \right] \geq \frac{\pi^m(\theta_l)}{n} - \rho f_l \end{aligned}$$

Replacing for the derived values of  $\pi^*$  allows us to re-write the previous condition as:

$$\Pi^{*C} \geq \Pi^L \Leftrightarrow \pi^m(\theta_l) \geq n\rho \left\{ \frac{[1-\delta(1-\rho)](1-\delta + \mu\delta\rho)(n-1)}{[(1-\delta + \delta\rho n)(1-\rho) - (n-1)\rho] \delta\mu} f_h + f_l \right\}$$

With the specific demand function the condition reads as:

$$\Pi^{*C} \geq \Pi^L \Leftrightarrow \theta_l \geq \frac{4n\rho}{(A-c)^2} \left[ \frac{[1-\delta(1-\rho)](1-\delta + \mu\delta\rho)(n-1)}{[(1-\delta + \delta\rho n)(1-\rho) - (n-1)\rho] \delta\mu} f_h + f_l \right]$$

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