

## Topics

# Iwan Bos\*, Wilko Letterie and Dries Vermeulen Antitrust as Facilitating Factor for Collusion

**Abstract:** This paper examines collusion among firms whose discount factors are private information. Mutual uncertainty regarding intentions to restrict competition might undermine the possibility of tacit collusion. Firms that want to collude may, however, reveal their intentions by consciously acting in breach of antitrust laws. As antitrust activity makes explicit collusion costly in expected terms, it can potentially be (ab)used as signaling device. We show that the fight against cartels may indeed facilitate collusion.

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## 1 Introduction

A, if not *the*, prime purpose of antitrust agencies around the globe is to deter cartel formation. Nevertheless, and despite the enhanced enforcement efforts over the last decades, new cartels are discovered each year. As recently stated by Levenstein and Suslow (2012, 2–3):

The incentive to coordinate behavior in order to increase profits is a powerful one. Despite the now widespread legal prohibitions on explicit coordination, firms continue to form cartels to restrict output or set prices.

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and

Perhaps the most surprising thing about cartels is how pervasive they are. Over a century after the United States first adopted laws making price-fixing a felony, and two decades after the U.S., the European Commission, and competition authorities around the world reached consensus that hard core cartels would not be tolerated, cartels continue to form.

These observations raise the question of why companies continue to act in violation of antitrust laws. In this paper, we provide a rationale for the persistence of cartel formation. We show that firms may fix their prices precisely because it is prohibited.

Our theory is based on the recognition that firms might be uncertain about each other's intentions to collude. In the context of repeated games, these intentions are reflected by a discount factor that firms use to determine the present value of expected cash flows. There are several other interpretations of the discount factor. It is frequently referred to as "level of patience". Alternatively, one can view it as "probability of a future" (*i.e.* a stop probability).<sup>1</sup> As is well known, effective collusion commonly requires conspirators to assign enough weight to future profits. A sufficiently high discount factor enables the adoption of punishment strategies to discourage participants from cheating on the agreement. As collusive contracts (such as price-fixing) typically cannot be enforced in court, this holds independent of whether firms use express or implicit communication to establish and sustain the cooperation. That is, both explicit and tacit collusive agreements must be self-enforcing.

In a recent paper, Harrington and Zhao (2012) have shown that tacit collusion can be quite a challenge for firms that have incomplete knowledge about each other's intentions to collude. Specifically, they study an infinitely repeated prisoners' dilemma in which discount factors are private information. Firms have either a low or a high discount factor, and only the latter is capable of sustaining supra-competitive prices. In this setting, a firm that is eager to collude faces the problem that its rival may not be willing to elevate prices. This firm can try to reveal its intentions by increasing its price, but this is a risky strategy as it may not be matched by its competitor. To avoid the risk of losing business, it can alternatively wait in the hope that its rival will initiate collusion. Harrington and Zhao (2012) find that in this case it might take long before firms come to a collusive agreement and that an agreement may not be reached at all.

This finding naturally leads to the question of whether firms can do better by colluding explicitly. To address this issue, we consider a similar setting as

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<sup>1</sup> See Shapley (1953).

Harrington and Zhao (2012) and extend it by giving firms the opportunity to communicate directly. Specifically, each firm has to indicate at the beginning of the game whether it wants to engage in a cartel. In case of consensus, the cartel is formed. In principle, the possibility of express communication will not be of much help in this context when talking is cheap. However, firms can make communication costly by consciously acting in breach of antitrust laws. Gathering to discuss selling prices, for example, makes communication costly in expected terms due to antitrust enforcement. Additionally, there may be costs associated with setting up and maintaining the agreement (e.g. bargaining and monitoring).

The fact that forming a cartel is not cheap potentially provides an opportunity for firms to signal their intentions. We start our analysis by deriving conditions under which tacit collusion is not feasible. Then, given these conditions, we prove the existence of a *chatty equilibrium* in which firms with a high discount factor find it profitable to collude explicitly. This requires that forming the cartel agreement is costly, but not too costly. It must be sufficiently costly to ensure that only firms capable of collusion have an incentive to communicate. At the same time, it should not be too costly so that cartel formation is still profitable. Additionally, we show that there are always conditions under which firms find it profitable to form a cartel, even when the cartel gets caught. Part of the reason is that cartel participants know each other's type and therefore can continue colluding tacitly after the cartel has been discovered and prosecuted. Thus, antitrust agencies can make cartel formation less attractive, but cannot completely avoid being used as signaling device.

With a few exceptions, existing literature on collusion does not make a clear distinction between tacit and explicit collusion. From an enforcement perspective, this is potentially problematic as the former is typically considered legal, whereas the latter is not.<sup>2</sup> As explicit collusion is costly, it is difficult to see why firms would use express communication if the same market outcome could be obtained in a tacit manner. One rationale for

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<sup>2</sup> In recent years, there is a growing interest in the distinction between the economic and legal approach to industrial collusion. For a discussion see, among others, Motta (2004), Whinston (2006) and Davies and Olczak (2008). Whereas economists generally do not distinguish between tacit and explicit collusion, lawyers require that firms have reached an agreement on one or more key strategic variables (e.g. prices or outputs). It is noteworthy that pinning down the exact meaning of "agreement" is a challenging exercise. See Kaplow (2011) for an extensive and detailed discussion of this matter.

explicit collusion is that direct communication helps in coordinating on (more profitable) collusive equilibria. For instance, absent a focal price it may be difficult to coordinate actions without express communication. Moreover, explicit collusion may be more profitable when there is uncertainty about demand.<sup>3</sup> Communication also potentially plays a significant role when firms hold private information about factors that affect the sustainability of collusion (e.g. past actions, actual prices, realized sales).<sup>4</sup> In particular, firms may exchange information to enhance market transparency, thereby reducing the risk of secret price cutting.<sup>5</sup> Our analysis offers an alternative explanation for explicit collusion. In our setting, firms communicate neither to coordinate on a particular (more profitable) equilibrium nor for monitoring purposes. Firms explicitly discuss their prices solely to credibly signal their willingness to collude.

There are a few other studies that also highlight potential adverse effects of antitrust activity. McCutcheon (1997), for instance, argues that the prohibition of price-fixing might facilitate collusion by preventing renegotiations in case of defection, thereby making punishment strategies of cartel participants credible and effective. Bos, Peeters, and Pot (2013) show that when buyers do not instantly respond to price changes, firms may wish to collude explicitly when the probability of getting caught is sufficiently high. In a recent experiment, Andersson and Wengström (2007) find that costly communication leads to higher prices and enhances the stability of cartels. Our analysis adds to these findings by showing that antitrust laws can be (ab)used as signaling device and as such can be considered a facilitating factor for collusion.

This paper proceeds as follows. In the next section, we present the basic structure and assumptions of the model. Section 3 explores possibilities for firms to collude tacitly and explicitly. Specifically, we derive conditions under which tacit collusion is not feasible and show that firms may still be capable of reaching collusive market outcomes through express communication. Section 4 concludes.

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<sup>3</sup> See Martin (2006) and Mouraviev (2012).

<sup>4</sup> The case where firms have imperfect information about each other's past actions has been studied by Compte (1998) and Kandori and Matsushima (1998). Harrington and Skrzypacz (2011) examine collusion when both prices and quantities are private information.

<sup>5</sup> Genesove and Mullin (2001) provide a detailed case study of a sugar-refining cartel. Among other things, they describe how the cartel mitigated incentives to cheat by making price cuts more transparent.

## 2 Model

We consider collusion in an infinitely repeated prisoners' dilemma when players' discount factor is private information. In this section, we present the basic structure of the model.

### Stage game

Let us start with a description of the stage game. There are two profit-maximizing firms, Firm 1 and Firm 2, that choose prices simultaneously. Each firm can either set a high price  $p_H$  or a low price  $p_L$ . If both firms charge the high price, then each firm receives a "collusive" profit  $\pi^c$ . If prices differ, then the low-priced firm makes a "deviation" profit of  $\pi^d$ . For simplicity, we make the innocuous assumption that the high-priced firm receives zero profit. When both firms choose the low price, each receives a "competitive" profit  $\pi^n$ . We follow the common assumption in theories of collusion that firms face a prisoners' dilemma when choosing their prices. This corresponds to the following pay-off ranking:  $\pi^d > \pi^c > \pi^n > 0$ . As a result, it is a dominant strategy for both firms to charge the low price and therefore  $(p_L, p_L)$  constitutes the unique static Nash equilibrium.

### Repeated game

In the following, we will study the infinitely repeated version of this game. To formalize, suppose that firms simultaneously set prices in each period  $t = 1, 2, 3, \dots$ . Let  $a_{it} \in \{p_L, p_H\}$  denote the action that firm  $i$  takes at time  $t$ . The pair of actions  $a_t = (a_{1t}, a_{2t})$  induces a pair of pay-offs  $\pi_{1t} = \pi_{1t}(a_t)$  and  $\pi_{2t} = \pi_{2t}(a_t)$ . Accordingly, firm  $i$  receives a stream of pay-offs  $\pi_{i1}, \pi_{i2}, \pi_{i3}, \dots$ . To determine the value of future profits, each firm uses a discount factor  $\delta_i$ . Thus, the present value of receiving  $\pi_{it}$  at time  $t$  is  $\delta_i^{t-1} \cdot \pi_{it}$  and cumulative profits are given by

$$\Pi_i = \sum_{t=1}^{\infty} \delta_i^{t-1} \cdot \pi_{it}.$$

### Information

Each firm has either a high or a low discount factor:  $\delta_i \in \{\delta_\ell, \delta_h\}$ , with  $0 < \delta_\ell < \delta_h < 1$ . Let  $\gamma \in (0, 1)$  be the probability that a firm is of the high type,  $\delta_h$ . With probability  $1 - \gamma$ , a firm is of the low type,  $\delta_\ell$ . To establish firms' discount factors, Nature performs an i.i.d. random draw from the probability

distribution  $(\gamma, 1 - \gamma)$  over types. After the realization of types, each firm is informed about its own type, but not about the type of its rival. Thus, discount factors are private information.

## Histories

Apart from the *ex ante* information on their discount factor, firms are also updated about the pairs of actions that were taken in all previous periods. These updates are recorded in histories. A history is a sequence  $h_t = (a_1, \dots, a_{t-1})$  of pairs of actions  $a_t = (a_{1t}, a_{2t})$ . We denote the set of all histories by  $\mathcal{H}$ . Notice that there is only one possible history at time  $t = 1$ , which is the empty sequence  $h_1 = ()$ .

## Plans of action

A *plan of action* is a function  $P : \mathcal{H} \rightarrow \{p_L, p_H\}$  from the set of histories  $\mathcal{H}$  to the set of actions  $\{p_L, p_H\}$ . The plan of action  $P$  specifies that, for each history  $h_t \in \mathcal{H}$ , the action  $P(h_t) \in \{p_L, p_H\}$  is chosen. In this paper, we consider the choice between a non-collusive and a collusive plan of action. The non-collusive plan of action  $N : \mathcal{H} \rightarrow \{p_L, p_H\}$  is defined by  $N(h_t) = p_L$  for all  $h_t \in \mathcal{H}$ . In this case, a firm always selects the low price. Alternatively, firms may attempt to collude by means of a grim-trigger strategy.<sup>6</sup> Specifically, the collusive plan of action  $T$  is defined by

$$T(h_t) = \begin{cases} p_H & \text{if } p_L \text{ has not been chosen in any previous round,} \\ p_L & \text{otherwise.} \end{cases}$$

## Realizations

Suppose that Firm 1 employs plan of action  $P_1$  and that Firm 2 employs plan of action  $P_2$ . In each period  $t$ , these choices induce a realized pair of

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<sup>6</sup> Note that charging a low price in each period following the period of defection is the most severe punishment strategy in our setting. Thus, if high prices cannot be sustained by adopting this strategy, then collusion will not occur in any (subgame perfect) equilibrium. Furthermore, and as will become clear in the ensuing analysis, we derive conditions under which tacit collusion is unfeasible and use this as a benchmark. In principle, one could perform similar analyses under alternative assumptions regarding the punishment strategy. This, however, would not affect our main conclusions.

actions  $a_t = (a_{1t}, a_{2t})$  as follows. At time  $t = 1$ , we define  $a_{11} = P_1(h_1)$ ,  $a_{21} = P_2(h_1)$  and  $a_1 = (a_{11}, a_{21})$ . Then, for a given history  $h_t = (a_1, \dots, a_{t-1})$ ,  $a_{1t} = P_1(h_t)$ ,  $a_{2t} = P_2(h_t)$  and  $a_t = (a_{1t}, a_{2t})$ . The expected pay-off for firm  $i$  is then given by

$$\Pi_i(P_1, P_2, \delta_i) = \sum_{t=1}^{\infty} \delta_i^{t-1} \cdot \pi_{it}(a_t).$$

## Strategies

In general, a strategy for firm  $i$  is a pair  $s_i = (s_{ih}, s_{i\ell})$ , where  $s_{ih} : \mathcal{H} \rightarrow \{p_L, p_H\}$  and  $s_{i\ell} : \mathcal{H} \rightarrow \{p_L, p_H\}$  are plans of action. The plan of action  $s_{ih}$  specifies that, for each history  $h_t \in \mathcal{H}$ , firm  $i$  will take action  $s_{ih}(h_t) \in \{p_L, p_H\}$  at time  $t$  when it is of the high type (i.e.  $\delta_i = \delta_h$ ). In a similar vein, the plan of action  $s_{i\ell}$  specifies that, for each history  $h_t \in \mathcal{H}$ , firm  $i$  will take action  $s_{i\ell}(h_t) \in \{p_L, p_H\}$  at time  $t$  when it is of the low type (i.e.  $\delta_i = \delta_\ell$ ).<sup>7</sup>

## Expected pay-offs

Consider a pair of strategies  $(s_1, s_2) = ((s_{1h}, s_{1\ell}), (s_{2h}, s_{2\ell}))$  and suppose that  $\delta_1 = \delta_\ell$ . In this case, Firm 1 can determine its expected pay-off,  $V_{1\ell}(s_1, s_2)$ , as follows. As it is of the low type, it will employ plan of action  $s_{1\ell}$ . It does not know the discount factor of its rival and, consequently, does not know whether Firm 2 will employ  $s_{2\ell}$  or  $s_{2h}$ . All it knows is that Firm 2 will employ  $s_{2h}$  with probability  $\gamma$  and  $s_{2\ell}$  with probability  $1 - \gamma$ . Its expected pay-off is therefore given by

$$V_{1\ell}(s_1, s_2) = \gamma \cdot \Pi_i(s_{1\ell}, s_{2h}, \delta_\ell) + (1 - \gamma) \cdot \Pi_i(s_{1\ell}, s_{2\ell}, \delta_\ell).$$

The expected values  $V_{1h}(s_1, s_2)$ ,  $V_{2\ell}(s_1, s_2)$  and  $V_{2h}(s_1, s_2)$  are determined in a similar fashion.<sup>8</sup>

<sup>7</sup> Strictly speaking, we could do without the specification of actions for histories that a firm's own actions prevent from happening. This, however, would significantly complicate our notation. We therefore follow standard practice in game theory by accepting the limited amount of redundancy associated with this way of modeling histories.

<sup>8</sup> Observe that, for example,  $V_{1h}(s_1, s_2)$  does only depend on the part  $s_{1h}$  of  $s_1$  and not on  $s_{1\ell}$ . We have chosen this modest amount of redundancy in our notation to avoid having to define all four variants of expected pay-offs separately.

### 3 Collusion

Let us now direct our attention to possibilities for firms to collude. We start by analyzing tacit collusion and derive conditions under which tacit collusion is not feasible. Then, given these conditions, we show that firms may still be willing and able to collude explicitly. In both cases, the solution concept is a Bayesian Nash equilibrium (BNE).

**Bayesian Nash equilibrium.** A pair of strategies  $(s_1, s_2)$  is a *Bayesian Nash equilibrium* when

$$V_{1h}(s_1, s_2) \geq V_{1h}(\tilde{s}_1, s_2) \quad \text{and} \quad V_{1\ell}(s_1, s_2) \geq V_{1\ell}(\tilde{s}_1, s_2)$$

for all strategies  $\tilde{s}_1$  of Firm 1, and

$$V_{2h}(s_1, s_2) \geq V_{2h}(s_1, \tilde{s}_2) \quad \text{and} \quad V_{2\ell}(s_1, s_2) \geq V_{2\ell}(s_1, \tilde{s}_2)$$

for all strategies  $\tilde{s}_2$  of Firm 2.

#### 3.1 Tacit collusion

Consider a pair of strategies  $(s_1, s_2) = ((s_{1h}, s_{1\ell}), (s_{2h}, s_{2\ell}))$  with  $s_{i\ell}, s_{ih} \in \{N, T\}$ . Thus, each firm chooses between the competitive plan of action  $N$  and the collusive plan of action  $T$ . Let us first focus on the choice of a firm with a low discount factor. The next result shows when  $s_{1\ell} = s_{2\ell} = N$  holds in equilibrium. The proofs of all results in this section are relegated to the appendix.

**Proposition 1.** *For a firm with a low discount factor,  $N$  is a strictly dominant plan of action when*

$$\delta_\ell < \frac{\pi^d - \pi^c}{\pi^d - \pi^n}.$$

Proposition 1 shows when firms with a low discount factor will not collude. Given this condition, the only remaining possible equilibria are  $((T, N), (T, N))$  and  $((N, N), (N, N))$ . It is clear that  $((N, N), (N, N))$  is an equilibrium regardless of the values of  $\delta_h$  and  $\delta_\ell$ . Moreover, if  $\delta_h < \frac{\pi^d - \pi^c}{\pi^d - \pi^n}$ , then firms with a high discount factor will not collude either. Therefore, suppose that  $\delta_h \geq \frac{\pi^d - \pi^c}{\pi^d - \pi^n}$  so that firms with a high discount factor may have an interest to collude tacitly. In fact, given this condition, a firm with a high discount factor is willing to collude provided that its rival also has a high discount factor and both firms know each other's type. Yet, in the current setting, firms do not know the type of their competitor. The next result shows when  $((T, N), (T, N))$  is still a BNE.

**Proposition 2.** *The pair of strategies  $((T, N), (T, N))$  is a BNE when*

$$\delta_h \geq \frac{\gamma(\pi^d - \pi^c) + (1 - \gamma)\pi^n}{\gamma(\pi^d - \pi^n) + (1 - \gamma)\pi^n}.$$

Observe that for  $\gamma \rightarrow 1$  the above condition reduces to  $\delta_h \geq \frac{\pi^d - \pi^c}{\pi^d - \pi^n}$ . Thus, a firm that is of the high type may be willing to collude when it is sufficiently certain that its rival is also of the high type. By contrast, when  $\gamma \rightarrow 0$ , then the above condition reduces to  $\delta_h \geq 1$ , which does not hold. Clearly, when a high type is sufficiently certain that its rival is of the low type, then it will prefer the non-collusive plan of action  $N$ . Finally, notice that collusion is more of a challenge in comparison to a situation where discount factors are common knowledge. In particular, two firms that are of the high type may no longer be willing to collude despite the fact that both might have the capability to sustain high prices.

### 3.2 Explicit collusion

On the basis of the above analysis, we now make the following assumption.

Assumption 1:

$$0 < \delta_\ell < \frac{\pi^d - \pi^c}{\pi^d - \pi^n} \leq \delta_h < \frac{\gamma(\pi^d - \pi^c) + (1 - \gamma)\pi^n}{\gamma(\pi^d - \pi^n) + (1 - \gamma)\pi^n}.$$

This assumption implies that both firms, independent of their type, prefer  $N$  to  $T$  and therefore excludes the possibility of tacit collusion.

In this section, we add an extra feature to the model by allowing firms to communicate directly and form a cartel. Specifically, after the information phase, both firms have to indicate whether they have an intention to collude. This is modeled as a choice from the set  $\{A, R\}$ , where  $A$  signifies the willingness to cartelize and  $R$  signifies refusal to collude. For a cartel to form, both firms have to choose  $A$ . We assume that explicit collusion is costly and when both firms choose  $A$ , their expected profit is reduced by a lump sum amount  $X > 0$ . The amount  $X$  has a broad interpretation. It may be thought of as an investment of private resources required to form and maintain the cartel agreement. As explicit collusion typically constitutes a violation of antitrust laws, it also captures the anticipated costs of antitrust enforcement (e.g. fines, prison terms, treble damages to private parties).<sup>9</sup> At the end of this section, we provide an example illustrating that  $X$  may indeed include both types of costs.

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<sup>9</sup> In jurisdictions with a leniency program,  $X$  also includes an expected leniency discount.

With the above extension, a low-type firm now makes a decision  $c_{i\ell} = (K_{i\ell}, c_{i\ell}^c, c_{i\ell}^n)$ , where  $K_{i\ell} \in \{A, R\}$  is the choice whether to signal intentions to collude,  $c_{i\ell}^c : \mathcal{H} \rightarrow \{p_L, p_H\}$  is the plan of action when both firms have indicated their willingness to form a cartel, and  $c_{i\ell}^n : \mathcal{H} \rightarrow \{p_L, p_H\}$  is the plan of action when at least one firm refuses to collude. A high-type firm draws a plan in a similar way.

In the following, let the rival of firm  $i$  be denoted by  $j$ . For a strategy pair  $c = (c_1, c_2)$ , with  $c_i = (K_{ih}, c_{ih}^c, c_{ih}^n, K_{i\ell}, c_{i\ell}^c, c_{i\ell}^n)$ , the pay-off  $V_{ih}(c_1, c_2)$  is defined as follows:

$$\text{If } K_{ih} = A, K_{jh} = A, K_{j\ell} = A, \quad [1]$$

$$\text{then } V_{ih}(c_1, c_2) = \gamma \cdot \Pi_i(c_{ih}^c, c_{jh}^c, \delta_h) + (1 - \gamma) \cdot \Pi_i(c_{ih}^c, c_{j\ell}^c, \delta_h).$$

$$\text{If } K_{ih} = A, K_{jh} = A, K_{j\ell} = R, \quad [2]$$

$$\text{then } V_{ih}(c_1, c_2) = \gamma \cdot \Pi_i(c_{ih}^c, c_{jh}^c, \delta_h) + (1 - \gamma) \cdot \Pi_i(c_{ih}^n, c_{j\ell}^n, \delta_h).$$

$$\text{If } K_{ih} = A, K_{jh} = R, K_{j\ell} = A, \quad [3]$$

$$\text{then } V_{ih}(c_1, c_2) = \gamma \cdot \Pi_i(c_{ih}^n, c_{jh}^n, \delta_h) + (1 - \gamma) \cdot \Pi_i(c_{ih}^c, c_{j\ell}^c, \delta_h).$$

$$\text{If either } K_{ih} = R, \text{ or } K_{ih} = A, K_{jh} = R, K_{j\ell} = R, \quad [4]$$

$$\text{then } V_{ih}(c_1, c_2) = \gamma \cdot \Pi_i(c_{ih}^n, c_{jh}^n, \delta_h) + (1 - \gamma) \cdot \Pi_i(c_{ih}^n, c_{j\ell}^n, \delta_h).$$

So, for instance, consider high-type firm  $i$  and suppose that this firm decides to indicate its willingness to collude (*i.e.* choose  $A$ ). Suppose further that its rival chooses  $A$  when it is of the high type and  $R$  when it is of the low type. In this case, the plans of action  $c_{ih}^c$  and  $c_{jh}^c$  are chosen with probability  $\gamma$ . With probability  $1 - \gamma$  firm  $i$ 's rival is of the low type, which in this particular case means it will indicate refusal to collude (*i.e.* choose  $R$ ). Consequently, as at least one firm chooses  $R$ , the plans of action  $c_{ih}^n$  and  $c_{j\ell}^n$  are chosen. Thus, firm  $i$ 's expected pay-off is given by eq. [2]. All other (expected) pay-offs, including  $V_{i\ell}(c_1, c_2)$ , are specified in a similar fashion.

In the following, equilibria of the extended game in which firms have the opportunity to communicate directly are referred to as *chatty equilibria*.

**Chatty equilibrium.** A pair of strategies  $(c_1, c_2)$ , with  $c_i = (K_{ih}, c_{ih}^c, c_{ih}^n, K_{i\ell}, c_{i\ell}^c, c_{i\ell}^n)$ , is a *chatty equilibrium* if

$$V_{1h}(c_1, c_2) \geq V_{1h}(\tilde{c}_1, c_2) \quad \text{and} \quad V_{1\ell}(c_1, c_2) \geq V_{1\ell}(\tilde{c}_1, c_2)$$

for all strategies  $\tilde{c}_1$  of Firm 1, and

$$V_{2h}(c_1, c_2) \geq V_{2h}(c_1, \tilde{c}_2) \quad \text{and} \quad V_{2\ell}(c_1, c_2) \geq V_{2\ell}(c_1, \tilde{c}_2)$$

for all strategies  $\tilde{c}_2$  of Firm 2.

The next result shows when the strategy pair  $(c_1, c_2)$ , with  $c_1 = c_2 = (A, T, N, R, N, N)$ , is a chatty equilibrium. In this case, firms with a high discount factor signal their intention to collude and follow the plan of action  $T$  accordingly provided that collusion is agreed upon. The non-collusive plan of action  $N$  is chosen in all other cases.<sup>10</sup>

**Proposition 3.** *The pair of strategies  $(c_1, c_2)$ , with  $c_1 = c_2 = (A, T, N, R, N, N)$ , is a chatty equilibrium when*

$$\frac{\pi^c - \pi^n}{1 - \delta_h} \geq X \geq \pi^d - \pi^n.$$

Proposition 3 provides conditions under which firms find it beneficial to collude explicitly. Firms that are willing and able to collude may successfully engage in a cartel when this is costly, but not too costly. The right inequality,  $X \geq \pi^d - \pi^n$ , indicates that talking should not be too cheap. That is, cartel formation must be sufficiently costly to prevent firms that are not willing to cooperate from fooling those that are. The left inequality,  $\frac{\pi^c - \pi^n}{1 - \delta_h} \geq X$ , shows that talking should also not be too expensive to ensure that the benefits from forming a cartel outweigh the costs. The next result reveals that the cost level that is required to generate this separating effect can always be realized.

**Corollary 4.** *There exists an  $X$  for which the pair of strategies  $(c_1, c_2)$ , with  $c_1 = c_2 = (A, T, N, R, N, N)$ , is a chatty equilibrium.*

Thus, when tacit collusion is not feasible, firms might still be capable of colluding explicitly provided that the price of forming the agreement is high, but not too high. We would like to emphasize that the above findings do not require the assumed homogeneous pay-offs. In case profits differ, the constraints should hold for each firm individually. Likewise, the costs associated with cartel formation need not be equal across firms. All that is required is that

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<sup>10</sup> Notice that, in principle, the fifth strategy element is irrelevant due to the choice of  $R$  by low-type firms. As a result, any pair of strategies  $(c_1, c_2)$ , with  $c_1 = c_2 = (A, T, N, R, *, N)$ , will yield the same outcome.

these costs fall within the range as specified in Proposition 3. Yet, even though the same logic applies, firm heterogeneity may make cartel formation more of a challenge.

From a policy perspective, it seems that there is not much antitrust agencies can do to prevent cartel formation from being sufficiently costly. That is to say, the lower bound on  $X$  is partly at the discretion of firms and can be arranged to hold by, for example, an up-front participation fee. The same does not necessarily hold for the upper bound on  $X$ . Here, antitrust authorities may attempt to make explicit collusion unprofitable by enhancing enforcement efforts. As the next result shows, however, no matter how high the (expected) costs of forming a cartel, it might remain a profitable alternative.

**Corollary 5.** *Fix  $X \geq \pi^d - \pi^n$ . There exist a  $\delta^* \in (0, 1)$  and a  $\gamma^* \in (0, 1)$  such that for all  $\delta > \delta^*$  and  $\gamma < \gamma^*$  the pair of strategies  $(c_1, c_2)$ , with  $c_1 = c_2 = (A, T, N, R, N, N)$ , is a chatty equilibrium.*

For any fixed (expected) cost associated with cartel formation, there are parameter combinations for which explicit collusion is an equilibrium. It should be emphasized that this holds even when the cartel gets caught and the antitrust penalty is exceptionally high. The reason is that, after the cartel is discovered, conspirators can continue colluding tacitly as they know each other's type. In this respect, it is noteworthy that there are several empirical studies that lend support to this finding. Sproul (1993), for example, discovered that for a sample of industries in which firms were convicted for price-fixing, prices rose in the years following the indictment. Feinberg (1980), Block, Nold, and Sidak (1981), Choi and Philippatos (1983), Newmark (1988) and Harrington (2004) all provide evidence of post-cartel prices that did not (immediately) return to their non-collusive levels. That explicit collusion might effectively set the stage for tacit collusion is also confirmed experimentally by Fonseca and Normann (2012). In principle, there could be several explanations for these observations. For instance, there might have been a substantial rise of input prices during the cartel phase. Also, the convicted cartels might have been efficient, cost-reducing coalitions. Our analysis suggests an alternative explanation, namely that tacit collusion has replaced explicit collusion.<sup>11</sup>

The above analysis does not imply that the main goal of achieving full deterrence is idle. Clearly, deterrence may be achieved through the imposition of sufficiently draconic punishments. In practice, however, it is difficult to

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<sup>11</sup> This explanation is also pointed out by Harrington (2004) and Whinston (2006, 32).

determine when the (expected) penalty is “sufficiently draconic”. Indeed, an implication of Corollary 5 is that antitrust policy cannot ensure deterrence. The reason being that key traits, such as a firm’s discount factor and the probability that this discount factor is sufficiently high, are difficult, if not impossible, to assess. The inability to accurately determine relevant firm characteristics prevents, or at least impairs, the imposition of sentences that are both adequate and realistic.<sup>12</sup> Let us conclude this section with a simple example to illustrate this point.

**Example 1** Suppose that  $X$  is given by

$$X = I + \sum_{t=1}^{\infty} \delta_h^{t-1} \cdot (1 - \alpha)^{t-1} \cdot \alpha \cdot F = I + \frac{\alpha \cdot F}{1 - \delta_h \cdot (1 - \alpha)},$$

where  $I \geq 0$  captures the investment of private resources to form and maintain the cartel,  $\alpha \in (0, 1)$  is the per-period probability of being caught and  $F$  is the antitrust penalty in case of conviction.

By Proposition 3, cartel formation is deterred when

$$I + \frac{\alpha \cdot F}{1 - \delta_h \cdot (1 - \alpha)} > \frac{\pi^c - \pi^n}{1 - \delta_h}.$$

As  $I + \frac{\alpha \cdot F}{1 - \delta_h \cdot (1 - \alpha)} > \alpha \cdot F$ , a penalty  $F \geq \frac{\pi^c - \pi^n}{\alpha \cdot (1 - \delta_h)}$  is sufficient to prevent firms from talking. Notice, however, that this condition critically depends on  $\delta_h$ , which is difficult to determine.

Apart from the fact that antitrust enforcement may be insufficient to deter explicit collusion, it may also facilitate cartel formation. To see this, suppose that  $I < \pi^d - \pi^n$ . Thus, absent antitrust, firms do not find it beneficial to collude. Yet, introducing antitrust policy may allow firms to collude when the expected penalty is such that

$$\frac{\pi^c - \pi^n}{1 - \delta_h} \geq I + \frac{\alpha \cdot F}{1 - \delta_h \cdot (1 - \alpha)} \geq \pi^d - \pi^n > I.$$

As before, this condition critically depends on  $\delta_h$ . Consequently, it is difficult, if not impossible, to determine an adequate level of penalization.  $\diamond$

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<sup>12</sup> Antitrust agencies indeed typically have limited discretion in determining the level of antitrust penalties. Note, however, that society at large has substantial discretion to adopt a different (more optimal) set of rules. Yet, there is no reason to believe that the legislature has superior information regarding the aforementioned firm characteristics. The problem of ensuring deterrence thus seems difficult to avoid. We are grateful to a referee for stressing this point.

## 4 Concluding remarks

Firms might be unable to reach collusive market outcomes in a tacit manner when they are uncertain about each other's intentions to collude. In this case, we have shown that consciously acting in breach of antitrust laws can be a profitable alternative. As antitrust enforcement makes explicit collusion costly in expected terms it potentially allows those eager to collude to reveal their true intentions. The underlying logic is similar to the "blood-in" strategy as sometimes employed by criminal gangs. This strategy urges a person who wants to join a gang to kill somebody in order to prove that he is a trustworthy partner in crime. In a related fashion, albeit less dramatic, firms may show their willingness to collude by gathering together and explicitly discuss their selling prices. Antitrust may thus effectively function as signaling device, thereby facilitating collusion.

The theory presented in this paper is not limited to cartel formation, but also applicable to some legal cooperative arrangements between firms. For example, in a notable number of instances firm alliances are equity-based joint-ventures. It is well known that these type of arrangements align the interests of firms participating in the partnership.<sup>13</sup> Our analysis then suggests that uncertainty about the intentions of partner firms may be resolved by such costly up-front equity investments. Moreover, and consistent with our theory, repeated ties between firms that have been engaged in an equity-based cooperative relationship are more likely to be based on a less costly non-equity partnership.<sup>14</sup>

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## Appendix: Proofs

**Proof of Proposition 1** Suppose that a firm with a low discount factor is confronted with a competitor that employs plan of action  $N$ . The plan of action  $N$  gives a strictly higher pay-off when

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<sup>13</sup> See Pisano (1989).

<sup>14</sup> See Gulati (1995).

$$\sum_{t=1}^{\infty} \delta_{\ell}^{t-1} \cdot \pi^n > \sum_{t=2}^{\infty} \delta_{\ell}^{t-1} \cdot \pi^n,$$

which holds.

Next, suppose that a firm with a low discount factor is confronted with a competitor that employs plan of action  $T$ . The plan of action  $N$  gives a strictly higher pay-off when

$$\pi^d + \sum_{t=2}^{\infty} \delta_{\ell}^{t-1} \cdot \pi^n > \sum_{t=1}^{\infty} \delta_{\ell}^{t-1} \cdot \pi^c.$$

Rearranging gives

$$\delta_{\ell} < \frac{\pi^d - \pi^c}{\pi^d - \pi^n}.$$

□

**Proof of Proposition 2** Suppose that a firm with a high discount factor faces a competitor that employs strategy  $(T, N)$ . The plan of action  $T$  gives a weakly higher pay-off than  $N$  when

$$\gamma \cdot \left[ \frac{\pi^c}{1 - \delta_h} \right] + (1 - \gamma) \cdot \left[ \frac{\delta_h \cdot \pi^n}{1 - \delta_h} \right] \geq \gamma \cdot \left[ \pi^d + \frac{\delta_h \cdot \pi^n}{1 - \delta_h} \right] + (1 - \gamma) \cdot \left[ \frac{\pi^n}{1 - \delta_h} \right].$$

Rearranging gives

$$\delta_h \geq \frac{\gamma(\pi^d - \pi^c) + (1 - \gamma)\pi^n}{\gamma(\pi^d - \pi^n) + (1 - \gamma)\pi^n}.$$

□

**Proof of Proposition 3** Consider firm  $i$  and suppose that the strategy of its rival is  $c_j = (A, T, N, R, N, N)$ . We check under which conditions  $c_i = (A, T, N, R, N, N)$  is a best response.

To begin, suppose that firm  $i$  has a low discount factor. Given the above pair of strategies, it will reject collusion and choose  $N$ . As collusion is rejected, its rival will choose  $N$  regardless of its type. Its pay-off is therefore given by

$$\frac{\pi^n}{1 - \delta_{\ell}}.$$

Now suppose that firm  $i$  chooses  $A$  instead. In that case, it faces a competitor that plays  $T$  when of the high type and  $N$  when of the low type. Since for a low type it is always a best response to play  $N$ , its pay-off is given by

$$\gamma \cdot \left[ \pi^d + \frac{\delta_\ell \cdot \pi^n}{1 - \delta_\ell} - X \right] + (1 - \gamma) \cdot \left[ \frac{\pi^n}{1 - \delta_\ell} \right].$$

Thus, the equilibrium condition for this case is

$$\frac{\pi^n}{1 - \delta_\ell} \geq \gamma \cdot \left[ \pi^d + \frac{\delta_\ell \cdot \pi^n}{1 - \delta_\ell} - X \right] + (1 - \gamma) \cdot \left[ \frac{\pi^n}{1 - \delta_\ell} \right].$$

Rearranging gives

$$X \geq \pi^d - \pi^n.$$

Next, suppose that firm  $i$  has a high discount factor. According to  $(c_1, c_2)$ , firm  $i$  colludes with firm  $j$  when firm  $j$  is also of the high type, but not when firm  $j$  is of the low type. Hence, its expected pay-off in this case is given by

$$\gamma \cdot \left[ \frac{\pi^c}{1 - \delta_h} - X \right] + (1 - \gamma) \cdot \left[ \frac{\pi^n}{1 - \delta_h} \right].$$

(1) Suppose that firm  $i$  chooses  $R$ . In this case, it faces a competitor  $j$  that plays  $N$ , irrespective of firm  $j$ 's type. Consequently, it is a best response for firm  $i$  to also play  $N$ , which gives a pay-off

$$\frac{\pi^n}{1 - \delta_h}.$$

Thus, the equilibrium condition is

$$\gamma \cdot \left[ \frac{\pi^c}{1 - \delta_h} - X \right] + (1 - \gamma) \cdot \left[ \frac{\pi^n}{1 - \delta_h} \right] \geq \frac{\pi^n}{1 - \delta_h},$$

which is equivalent to

$$\frac{\pi^c - \pi^n}{1 - \delta_h} \geq X.$$

(2) Now suppose that firm  $i$  chooses  $A$ . In this case, it faces a competitor that plays  $T$  when of the high type and  $N$  when of the low type. If firm  $i$  now chooses  $N$  instead, its pay-off is

$$\gamma \cdot \left[ \pi^d + \frac{\delta_h \cdot \pi^n}{1 - \delta_h} - X \right] + (1 - \gamma) \cdot \left[ \frac{\pi^n}{1 - \delta_h} \right].$$

Therefore, the equilibrium condition in this case is

$$\gamma \cdot \left[ \frac{\pi^c}{1 - \delta_h} - X \right] + (1 - \gamma) \cdot \left[ \frac{\pi^n}{1 - \delta_h} \right] \geq \gamma \cdot \left[ \pi^d + \frac{\delta_h \cdot \pi^n}{1 - \delta_h} - X \right] + (1 - \gamma) \cdot \left[ \frac{\pi^n}{1 - \delta_h} \right].$$

Rearranging gives

$$\delta_h \geq \frac{\pi^d - \pi^c}{\pi^d - \pi^n},$$

which holds by Assumption 1.  $\square$

**Proof of Corollary 4** By Proposition 3, it must hold that  $\frac{\pi^c - \pi^n}{1 - \delta_h} \geq X \geq \pi^d - \pi^n$ . There exists an  $X$  for which this condition is satisfied when  $\frac{\pi^c - \pi^n}{1 - \delta_h} \geq \pi^d - \pi^n$ .

Rearranging gives  $\delta_h \geq \frac{\pi^d - \pi^c}{\pi^d - \pi^n}$ , which holds by Assumption 1.  $\square$

**Proof of Corollary 5** By Proposition 3, it must hold that  $\frac{\pi^c - \pi^n}{1 - \delta_h} \geq X \geq \pi^d - \pi^n$ . By assumption,  $X \geq \pi^d - \pi^n$ . The condition  $\frac{\pi^c - \pi^n}{1 - \delta_h} \geq X$  is satisfied when  $\delta_h \geq \delta^* = 1 - \frac{\pi^c - \pi^n}{X}$ . In addition, we know by Assumption 1 that

$$\frac{\pi^d - \pi^c}{\pi^d - \pi^n} \leq \delta_h < \frac{\gamma(\pi^d - \pi^c) + (1 - \gamma)\pi^n}{\gamma(\pi^d - \pi^n) + (1 - \gamma)\pi^n}.$$

As  $X \geq \pi^d - \pi^n$ , if  $\delta_h \geq 1 - \frac{\pi^c - \pi^n}{X}$ , then  $\delta_h \geq \frac{\pi^d - \pi^c}{\pi^d - \pi^n}$ . Thus, there exists a  $\delta_h$  for which  $(c_1, c_2)$ , with  $c_1 = c_2 = (A, T, N, R, N, N)$ , is a chatty equilibrium when

$$\frac{\gamma(\pi^d - \pi^c) + (1 - \gamma)\pi^n}{\gamma(\pi^d - \pi^n) + (1 - \gamma)\pi^n} > 1 - \frac{\pi^c - \pi^n}{X}.$$

Rearranging gives

$$\frac{1}{X} > \frac{\gamma}{\gamma(\pi^d - \pi^n) + (1 - \gamma)\pi^n}.$$

Observe that this requirement holds for  $\gamma = 0$  and does not hold for  $\gamma = 1$ . It is straightforward to check that this inequality holds for any  $\gamma < \gamma^* = \frac{\pi^n}{X - (\pi^d - \pi^n) + \pi^n}$ .  $\square$

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