Banning Information Exchange to Fight Collusion? Bananas and Beyond

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Abstract

We examine the relation between oligopolist's exchange of *prospective* information and collusion, and the extent to which a ban of such exchange may be desirable for consumers. We use a repeated framework to argue that, while the sharing of such information may be sustained in equilibrium along with collusive activity, firms *need not* communicate this kind of information for collusion. Hence, an antitrust policy which bans the sharing of prospective information may not restore competition and, as such, leave consumers worse off. Moreover, we show that, from a firms' point of view, information sharing may actually have a destabilizing effect on collusive activity.

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1 Introduction

Section 1 of Article 101 of the Treaty on the Functioning of the European Union outlaws agreements between undertakings, decisions by associations of undertakings and concerted practices "[...] which have as their *object or effect* the prevention, restriction or distortion of competition within the internal market [...]".[1] It is settled case-law that concerted practices with an anticompetitive object are prohibited, regardless of their effect.[2] Hence, once it is established that parties had a joint intention to collude, it is not necessary to appraise the effects of such practice. Typical evidence for an anticompetitive object is the exchange of information on prices, sales volumes and market conditions. The legal standard is a *per se* rule. However, "it is in some sense paradoxical that the least contested area of antitrust is perhaps the one in which the basis of the policy in economic theory is weakest" (Whinston, 2006, p.14).

Considering information exchange to be evidence for collusive intent may be problematic from an economic point of view. In a recent cartel case, the European Commission (EC) alleged the banana importers Chiquita, Dole, Del Monte and Weichert of fixing prices in Northern Europe between 2000 and 2002 on the basis of secret bilateral pre-pricing communications. During the relevant period, European banana imports were subject to an annual quota broken down into quarterly amounts with some limited flexibility between quarters. The import licences were allocated on the basis of imports in an earlier reference period. While the quota system imposed a ceiling, the threat of loosing future license entitlements put a floor on bananas entered into the EU. Economic theory would suggest that fixed supply prevents any anticompetitive effect of concerted practices. Hence, it would seem unlikely that the importers, knowing that any anticompetitive *effect* is impossible, exchanged information with a collusive *object*. The EC, however, held on to its allegations and fined Dole, Del Monte and Weichert a total of 60.3 million euros. Chiquita benefitted from amnesty under the leniency program because it had provided information to the EC enabling it to open an investigation.[3]

[1] Official Journal 115, 09/05/2008 p.0088-0089.

[2] In other words: "If there is a presumption that, following contacts between undertakings, their future conduct will automatically take account of the information exchanged, the Commission can infer the existence of a concerted practice in these cases without having to demonstrate that concertation was actually put into effect or that it produced any anticompetitive effects." (Albors-Llorens, 2006, p.12).

[3] EC IP/08/1509, October 2008.

The economic literature contains two different views on the motives for information sharing among competitors. One view is that the sharing of *retrospective* information can facilitate collusion.[4] In the model of Green and Porter (1984), imperfect monitoring of the rival's past actions causes costly price wars each time a bad demand realization is observed. Information about the rival's past actions would allow the firms to distinguish between a deviation and an exogenous demand fluctuation and therefore to avoid indiscriminate price wars. A contrasting view is that the sharing of *prospective* information between firms is compatible with competition. Firms faced with demand or cost uncertainties may be better able to tailor their output and pricing decisions to actual market conditions if they have access to the competitor's signal as well as their own private signals. Competing firms may thus wish to share prospective information.

While economic research widely agrees on the first view, it is not unanimous with respect to the non-collusive object behind the exchange of prospective information. This is an issue of particular relevance for antitrust policy because, provided that the firms act competitively in the product market, information sharing can be socially beneficial. If, however, the exchange of information goes hand in hand with collusive behavior, it may be better prevented.

An extensive theoretical literature examines whether firms have incentives for non-collusive information sharing. As far as Cournot oligopoly is concerned, Clarke (1983a,b), Vives (1984), Gal-Or (1985) and Li (1985) found that firms which produce substitute goods and act competitively do not wish to share information when uncertainty is on a common demand parameter. No sharing is the unique subgame perfect Nash equilibrium. The intuition for this result is simple: The sharing of information correlates the firms' output decisions positively. A parallel shift of a firm's reaction function following the realization of it's own signal is accompanied by a parallel shift of its rival's reaction function in the same direction. With strategic substitutes the reaction functions slope negatively and the variation of output is reduced which in turn decreases each firm's expected profit. Hence, each competitor can increase its expected profit by remaining silent about its private signal. Information sharing may therefore be revealing of cooperative behavior. This outcome may be reversed when firms have quadratic total costs (Kirby, 1988). If the cost coefficient is sufficiently large, errors in production and therefore, variation in output become very costly and information shar-

[4] See also Stigler (1964), Posner (1976) and Spence (1978).

ing constitutes an equilibrium of the game, even if firms act non-cooperatively in their output decisions. A similar reasoning leads to information sharing as an equilibrium outcome in Hviid (1989) when firms are risk averse. Bertrand competition or uncertainty about a private cost parameter may reverse the no-sharing result (Vives, 1984; Fried, 1984; Li, 1985; Shapiro, 1986).[5]

One shortcoming of the literature on prospective information sharing to date is that it is typically based on *static* models with two stages. In the first stage, information sharing takes place, and in the second stage, each firm chooses its product-market action. When firms unilaterally have to commit whether to share information prior to their product-market actions, they face a typical prisoners' dilemma situation in which no sharing is a strictly dominant strategy.[6] Based on the result that firms, acting competitively, do not wish to communicate, collusion is a seemingly straightforward explanation for the observed information sharing. Collusion as a reason for information sharing can however not be modeled in a static setting and must therefore be assumed. A repeated setting may thus provide better insights. An important feature of repeated non-cooperative games played between oligopolists however is that the firms need not communicate in order to collude. This phenomenon is known as 'tacit collusion'. If firms can tacitly collude, it is a priori not clear whether information sharing should be regarded as a sign for collusion. Even if it was a sign for collusion, a ban of information sharing, instead of restoring competition, would simply make tacit collusion more likely and leave consumers even worse off.

In the present paper, we address three different issues: First, we formalize the idea that information sharing, like collusive activity, is inherently dynamic. In the presence of repeated interactions, firms may be able to sustain collusion through trigger strategies in the absence of communication. Here we ask whether information sharing can be an indicator for collusion on the product market. Second, we examine how an antitrust policy that effectively bans information exchange between firms affects consumer welfare. Finally, we study the different effects of information sharing on cartel stability.

We have three main results: *First*, in the limit, if firms are arbitrarily patient, they

[5]Raith (1996) presents a general model that encompasses the models of the above literature as special cases.

[6]With quid pro quo sharing agreements, i.e. a firm receives information only if it shares its own signal, no disclosure can only be weakly dominant, and the stage game exhibits two equilibria. See Raith (1996) for details.

can sustain any possible degree of product-market collusion, namely any quantity combinations between the fully competitive and the fully collusive ones. We find that all the combinations sustainable without information exchange can also be implemented with information exchange. Hence, if firms are arbitrarily patient, the set of possible equilibria of the repeated game displays absolutely no correlation between information exchange and degree of collusion (i.e., the degree to which average payoffs exceed those of the stage-game equilibrium). *Second*, again in the limit, a ban on information sharing pushes colluding firms which also communicate to switch to tacit collusion. This switch can cause a loss to consumers through the firms' acting under more uncertainty, but, at the same time, provided that it reduces the degree of collusion, may also involve a gain. The size of the latter effect depends on the degree of collusion the firms can sustain in the absence of information sharing. Since the firms can tacitly collude, a ban on information exchange does not necessarily restore competition, and the gain in consumer surplus due to a lower degree of collusion may be too small to outweigh the loss due to firms facing higher uncertainty. *Third*, for finitely patient firms, we find that information sharing may actually decrease cartel stability. This is due to the fact that more information can strengthen the firms' deviation payoffs by allowing them to better tailor their deviations to the prevailing market conditions.

Our contribution formalizes the idea that information sharing, being part of a long-term relationship, can be collusive. However, in contrast to what has been argued in some of the previous literature, we doubt that a per se rule or, equivalently, a ban on information sharing may help to achieve the objectives set out by an effective antitrust enforcement policy. Our results suggest that an approach which is solely based on communication as an object without rigorously appraising the effects of such practice can be detrimental to consumer welfare.

The remainder of the paper is organized as follows. Section 2 sets up the model. Section 3 establishes a Folk Result and examines how banning information exchange affects consumer welfare when firms are arbitrarily patient. Section 4 discusses the effect of information exchange on cartel stability when firms are finitely patient. Section 5 briefly concludes.

2 The Model

2.1 Stage Game

In each period $t = 0, 1, 2, \ldots$, the following generic (two-stage) stage game is played between two symmetric firms $i = 1, 2$:

Stage 1

(1) *Disclosure Choice:* Each firm decides whether or not to disclose any private information which it learns in this period (choice assumed observable to other); denote this choice by $d_i \in \{\mathrm{y}, \mathrm{n}\}$.

(2) *Parameter Realization:* For each firm i, a parameter $\theta_i \in \Theta_i$ is drawn from some joint distribution $f(\theta_i, \theta_j)$ (assumed i.i.d. over time) where $i \neq j$.

(3) *Learning of Own Signal:* Each firm i learns private informative signal $\tilde{\theta}_i$ on θ_i.

(4) *Learning of Other's Signal:* If $d_i = \mathrm{y}$ in step (1) above, firm j learns the other firm i's signal $\tilde{\theta}_i$ regardless of whether firm j has decided to disclose. If $d_i = \mathrm{n}$ firm j learns nothing on the other's signal.

Stage 2

(5) *Product-Market Actions:* Each firm i chooses its product-market action x_i (prices or quantities) (choice assumed observable to other).

(6) *Profit Realization:* Firms' stage-game profits $\pi_i(x_i, x_j; \theta_i, \theta_j)$ materialize.

(7) *Monitoring:* Each firm learns the entire history of the game.

We focus on unilateral disclosure with pre-commitment. With unilateral disclosure a prisoner's dilemma situation may arise in the stage game and incentives to reveal information are weakest. The pre-commitment assumption is made for tractability. If firms can decide whether or not to disclose their private signal after its realization, mere nondisclosure can have a signaling effect on the other party. We moreover exclude partial revelation, i.e. each firm has to decide whether to reveal its signal completely or not at all. Finally, in the end of each period, in step (7), the firms learn the entire history of the game and thereby, the other firm's signal. The resolution of all uncertainty in the end of each period is crucial to ensure perfect monitoring of the competitor's actions. Perfect monitoring allows firms to distinguish *ex post* between cooperative product-market actions based on private signals and unilateral deviations. This assumption allows us to focus on the sharing of prospective rather than retrospective information and avoids monitoring problems associated with the latter, as in e.g. Green and Porter (1984).

The above set-up is very general and comprises several specific cases previously considered in the literature:

Example 1 (Symmetric Differentiated Cournot Duopoly with Substitutes and Uncertainty on a Common Demand Intercept)**.** Inverse demand in the product-market stage is linear and given by $p_i = a - bq_i - cq_j$, $b \geqslant c$, and firms' product-market actions correspond to output choices, i.e. $x_i = q_i$. Prior to choosing quantities, each firm learns a private signal on the demand intercept a.

Example 2 (Symmetric Differentiated Bertrand Duopoly with Substitutes and Uncertainty on a Common Demand Intercept)**.** Analogous to Example 1, except that the firms' product-market actions correspond to price choices, i.e. $x_i = p_i$.

Example 3 (Symmetric Differentiated Cournot Duopoly with Substitutes and Uncertainty on Private Costs)**.** Analogous to Example 1, except that, prior to setting its quantity, each firm privately learns its production costs c_i.

2.2 The Stage-Game Equilibrium

To find the equilibrium of the stage-game, we proceed by backwards induction: In the second stage, the firms noncooperatively set quantities or prices so as to maximize expected profits conditional on the information made available in stage 1.

In the first stage, given that the firms act cooperatively in the product market, the firms' incentives for information sharing depend on the type of competition (Cournot or Bertrand), the nature of the goods (substitutes or complements) and the type of uncertainty (on demand or costs).

For a symmetric differentiated Cournot duopoly with substitute goods and uncertainty on a common demand intercept (Example 1), no sharing is the unique subgame perfect Nash equilibrium. The intuition is simple: The sharing of information correlates the firms' output decisions positively. When the firms share information, a parallel shift of a firm's reaction function following a realization of it's own signal is accompanied by a shift of its rival's reaction function in the same direction. With strategic substitutes the reaction functions slope negatively, and a firm that conceals the realization of a high signal can produce more at a higher price compared to the situation of sharing. The reverse is true when the realized signal is low. Concealing information makes the firm produce less to a lower price. Since prices are higher when demand is high, the gain accrued from no sharing more than compensates the loss from concealing. Hence, not to share information is a dominant strategy for each firm and constitutes the unique subgame perfect Nash equilibrium of the two-stage game. See e.g. Vives (1984), Gal-Or (1985) and Li (1985).

For a symmetric differentiated Bertrand duopoly with substitute goods and uncertainty on a common demand intercept (Example 2) the above logic is reversed. When the firms' reaction functions slope positively, a firm gains more from unilaterally sharing information when its private signal is high than what it looses from sharing when the realized signal is low. Hence, to share information is a dominant strategy for each firm and thus constitutes the unique subgame perfect Nash equilibrium of the two stage game. See e.g. Vives (1984).

Let us briefly consider the case where the uncertainty is on the firms' private costs. As far as Cournot is concerned (Example 3), it is straightforward that information sharing is the unique subgame-perfect Nash equilibrium of the game. The reason is that with strategic substitutes, each firm's gain accrued from the revelation of low costs more than compensates each firm's loss caused by the revelation of high costs. See e.g. Li (1985).

In what follows, we let $\overline{\pi}_i$ denote firm i's ex-ante expected payoff in the stage-game equilibrium.

2.3 The Repeated Game: Some Terminology

Firms discount future payoffs by a common discount factor $\delta \in [0,1]$. Our analysis restricts attention to equilibria which are stationary along the equilibrium path. We call such a set of stationary equilibrium actions $(\mathbf{d}, \mathbf{x}(\tilde{\theta}))$ an 'action plan'.

Definition 1. For any δ, we call an action plan $(\mathbf{d}, \mathbf{x}(\tilde{\theta}))$ *implementable* if there exist strategies such that in any period t given signal realization $\tilde{\theta}_t$, actions $(\mathbf{d}, \mathbf{x}(\tilde{\theta}_t))$ are taken along the equilibrium path.

Definition 2. We say that a set of product-market action plans $\mathbf{x}(\tilde{\boldsymbol{\theta}}) \equiv (x_1(\tilde{\boldsymbol{\theta}}), x_2(\tilde{\boldsymbol{\theta}}))$ *does not require info exchange* if x_i is independent of $\tilde{\theta}_j$ for $i \neq j \in \{1,2\}$.

3 Information Exchange with Arbitrarily Patient Firms

In the Folk spirit and as a natural counterpart to the one-shot game, this section considers the set of equilibria of the game in the limit as $\delta \to 1$. We first state a common Folk Result by the means of which we then examine how a ban on information exchange between cooperating firms affects consumer surplus. For the latter purpose we take two different perspectives: First, we assume that the antitrust authority can select its preferred equilibrium outcome. Second, we examine the case where the firms can coordinate on their preferred equilibrium.

3.1 A Folk Result

This section describes the set of equilibria of the repeated game as $\delta \to 1$. As noted above, we consider only stationary equilibria in which the outcome along the equilibrium path can be described by an action plan $(\mathbf{d}, \mathbf{x}(\tilde{\boldsymbol{\theta}}))$. Moreover, to keep things as simple as possible for the time being, we will consider only equilibria in which punishment consists of indefinite reversion to the stage-game equilibrium. More specifically, after any deviation from the equilibrium behavior described by $(\mathbf{d}, \mathbf{x}(\tilde{\boldsymbol{\theta}}))$, parties play their stage-game equilibrium strategies in all future periods. If the deviation occurred in the information disclosure choice $\mathbf{d}$, the product-market-action strategies in the concurrent period are determined by the (Bayesian) Nash equilibrium of the second stage of the stage game (i.e., taking information-disclosure choices as given).[7] Notice that at this

[7]Future research shall clarify the extent to which this simplification involves no loss of generality. A first intuition suggests that no loss of generality is involved when it comes to describing the efficient frontier (efficient from firms' point of view) as $\delta \to 1$ (see Section 3.2.2 in particular). There may however be some loss of generality concerning the *lower* bound on firms' average payoff in equilibrium (as is relevant in Section 3.2.1) in the sense that average payoffs lower than the stage-game equilibrium payoffs may be feasible. This will be the case when minmax payoffs in the stage-game fall short of $\overline{\pi}_i$. Moreover, some loss of generality may be involved in our discussion of 'critical discount factors' in Section 4 in the sense that Nash reversion may not be an *efficient* punishment in the sense of sustaining an equilibrium outcome at the lowest possible δ. It should also be pointed out, however, that our stage game is a *sequential* game, so that the usual results on optimal penal codes (Abreu, 1988, 1986) do not apply (see Mailath et al., 2008).

point, our perfect-monitoring assumption that firms learn the entire history of the game at the end of each stage is crucial: By this, even without information exchange, firms learn *ex post* whether their competitor adhered to the product-market action schedule $x_j(\theta_j)$ or not.

With these types of strategies in mind, the following is essentially a straightforward application of the Folk Theorem (Friedman, 1971) to our setting:[8,9]

Proposition 1. *For δ large enough, the set of implementable stage-game product-market action plans is* $\mathbf{X} \equiv \{\mathbf{x}(\tilde{\boldsymbol{\theta}}) \mid \mathrm{E}_{(\tilde{\boldsymbol{\theta}},\boldsymbol{\theta})}[\pi_i(\mathbf{x}(\tilde{\boldsymbol{\theta}});\boldsymbol{\theta})] \geqslant \overline{\pi}_i, i = 1,2\}$.[10]

Proof. Can be established by simple trigger-strategy equilibrium (i.e., one-shot-Nash-Equilibrium reversion) upon any deviation combined with the fact that deviation payoffs in the deviation period are necessarily bounded. □

Having $\mathbf{d} \neq \{\mathrm{y},\mathrm{y}\}$ rather than $\mathbf{d} = \{\mathrm{y},\mathrm{y}\}$ only imposes the additional restriction $\partial x_i/\partial\tilde{\theta}_j = 0$ on $\mathbf{x}(\tilde{\boldsymbol{\theta}})$, and does not enter the implementability condition in Proposition 1 in any other way. Therefore, a trivial implication of Proposition 1 is the following:

Corollary 2. *For δ large enough, any action plan $\mathbf{x}(\tilde{\boldsymbol{\theta}})$ which is implementable with $\mathbf{d} \neq (y,y)$ can also be implemented with $\mathbf{d} = (y,y)$.*

That is, in the limit, the set of equilibria *with* information exchange contains those *without* information exchange.

Proposition 1 and Corollary 2 are illustrated in Figure 1 in the usual Folk-Theorem fashion, that is, by plotting players' feasible combinations of average expected payoffs $\pi(\mathbf{X})$ in the repeated game. Obviously, the lower bounds (players' stage-game-equilibrium payoffs $\overline{\pi}_i$) are unaffected by whether information is exchanged on the

[8] 'Essentially', because like most standard versions of the Folk Theorem, the Folk Theorem in Friedman (1971) covers repeated *static* stage games, whereas our two-stage stage game is sequential. As such, a one-to-one application of the theorem delivers feasible equilibrium action plans in any Nash equilibrium, but not necessarily subgame perfect. It is easily checked, however, that the strategies described above (in particular the concurrent response in second-stage product-market actions to deviations in first-stage information disclosure) satisfies the additional requirement of subgame perfection.

[9] Notice that Proposition 1 describes only feasible product-market action plans $\mathbf{x}(\tilde{\boldsymbol{\theta}})$ rather than feasible action plan $(\mathbf{d},\mathbf{x}(\tilde{\boldsymbol{\theta}}))$. This formulation is more convenient for our purpose since, *given* any $\mathbf{x}(\tilde{\boldsymbol{\theta}})$, the information-disclosure choices $\mathbf{d}$ are payoff irrelevant to both firms and consumers are concerned (in other words, $\mathbf{d}$ is payoff relevant only via its effect on $\mathbf{x}(\tilde{\boldsymbol{\theta}})$).

[10] Strictly speaking, $\mathbf{X}$ is actually the *closure* of the set of implementable stage-game product-market action plans in the sense that not all $\mathbf{x}(\tilde{\theta})$ for which $\mathrm{E}_{(\tilde{\boldsymbol{\theta}},\boldsymbol{\theta})}[\pi_i(\mathbf{x}(\tilde{\boldsymbol{\theta}});\boldsymbol{\theta})] = \overline{\pi}_i$ are implementable even as $\delta \to 1$.

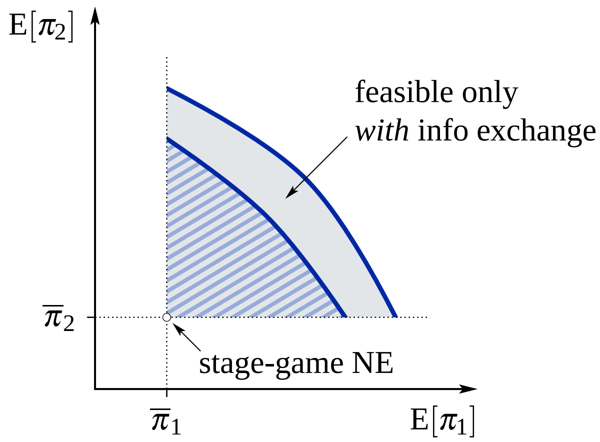


Figure 1: Illustration of Proposition 1 and Corollary 2 in Terms of Firms' Feasible Expected Payoffs.

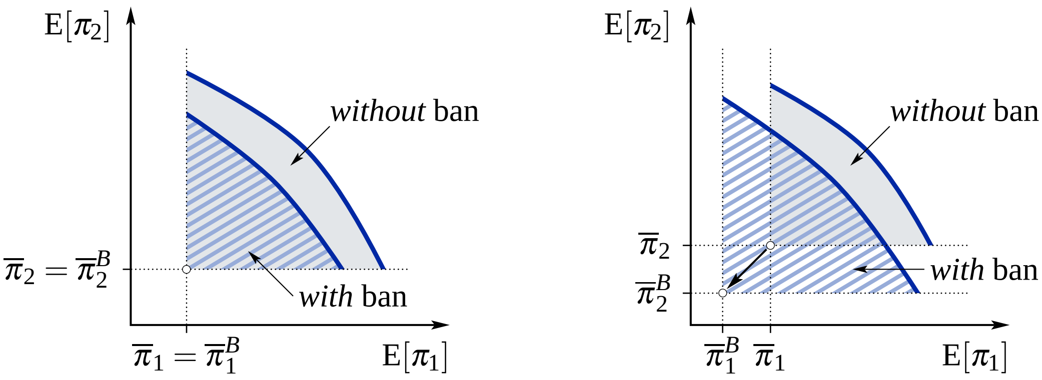
equilibrium path or not. On the other hand, to the extent that information exchange only *expands* the set of implementable product-market action profiles, information exchange on the equilibrium path will typically make it possible to attain Pareto-superior payoffs (at least weakly so), as illustrated by an outward shift in the frontier.

When interpreting Figure 1 it is important to bear in mind that most points in the shaded areas (i.e., feasible combinations of average expected payoffs) are actually attainable with a variety of different product-market action profiles $\mathbf{x}(\boldsymbol{\theta})$—each in turn with very different effects on consumers. We will get back to this below.

Notice that Corollary 2 already puts a subtle but important qualifier on the previous literature's argument that information exchange is an *indicator* of the degree of collusion: In our model, if firms are arbitrarily patient, the set of possible equilibria of the repeated game displays absolutely no correlation between information exchange and the degree of collusion (i.e., the degree to which average payoffs exceed those of the stage-game equilibrium).

3.2 Banning Information Exchange

The previous section has provided a look at the extent to which the equilibrium of the repeated game will involve information exchange if firms are *free* in their choice to exchange information. Next, we want to investigate the impact of a *ban* (by antitrust au-



(a) stage-game NE *has no* information exchange

(b) stage-game NE *has* information exchange

Figure 2: The Effect of a Ban on Information Exchange on Firms' Feasible Payoffs.

thorities, say) on information exchange—and the extent to which this may be desirable from consumers' point of view.[11]

Importantly, and in contrast to the previous section, a ban on information exchange also affects what firms are permitted to do *off* the equilibrium path. In particular, it affects the actions available on the punishment path. To account for this, let $\overline{\pi}_i^B$ denote the payoffs in the stage-game equilibrium payoffs *with* a ban. Then the following result is straightforward:

Proposition 3. *With a ban on information exchange and for δ large enough, the set of implementable product-market action plans is* $\mathbf{X}^B \equiv \{\mathbf{x}(\tilde{\boldsymbol{\theta}}) \mid \mathrm{E}_{(\tilde{\boldsymbol{\theta}},\boldsymbol{\theta})}[\pi_i(\mathbf{x}(\tilde{\boldsymbol{\theta}});\boldsymbol{\theta})] \geqslant \overline{\pi}_i^{\mathrm{B}}$, *and* $\partial x_i/\partial\tilde{\theta}_j = 0$, $i \neq j \in \{1,2\}\}$.

Thus, an antitrust policy which bans information exchange between firms has the effect of changing the set of equilibrium product-market action plans from $\mathbf{X}$ to $\mathbf{X}^B$, as defined by Propositions 1 and 3, respectively. Figure 2 again illustrates the effect of a ban in terms of firms' feasible payoffs—and the fact that the set of equilibria is affected differently depending on whether the equilibrium of the original stage game has information exchange (in which case $\overline{\pi}_i^B = \overline{\pi}_i$, as in panel (a)) or not (as in panel (b)).

[11] One could imagine e.g. that the antitrust authority uses communication as hard evidence to establish the existence of a cartel and to impose high fines. It rests with the firms to prove the non-collusive object of this exchange at the occasion of an official hearing. This typically involves heavy costs for the firms.

Whether a ban is desirable is a priori unclear, however, because the set of feasible equilibria with and without a ban can generally not be ranked (i.e., consumers will prefer *some* $\mathbf{x}(\tilde{\boldsymbol{\theta}}) \in \mathbf{X}$ to some $\mathbf{x}(\tilde{\boldsymbol{\theta}}) \in \mathbf{X}^B$, and vice versa).

To make a comparison feasible, we will therefore investigate the impact of a ban under two alternative assumptions concerning equilibrium selection under either regime: *First*, we assume that—with or without a ban—the antitrust authority can coordinate firms on *its* preferred equilibrium, and *second*, we assume that firms can coordinate on *their* preferred equilibrium under either regime.

To put these two approaches into perspective, note that the previous literature has usually posited a more or less *ad hoc* link between information sharing and collusion. In contrast, our approach in the context of a repeated game attempts to isolate the effect of information exchange by checking the effect of a ban if the 'least collusive' equilibrium is selected in either regime (as reflected by the antitrust authorities' preferred equilibria), or if the 'most collusive' equilibrium is selected (as reflected by firms' preferred equilibria). Put differently: We isolate the effect of information exchange from the accompanying level of collusion by accounting for the fact that, even without exchanging information, firms may tacitly collude as best they can, and that, even with an exchange of information, firms may act competitively (as captured by the equilibria of our repeated game).

3.2.1 Equilibrium Selection by the Antitrust Authority

Assume first that, with or without information exchange, the antitrust authority can coordinate firms on its preferred equilibrium. Moreover, suppose that consumer welfare is the ultimate objective of the antitrust authority.[12]

Assume first that $\overline{\pi}_i^B \geqslant \overline{\pi}_i$, which will be the case if the stage-game equilibrium without a ban does not have firms exchange information, or if it does but the exchange of information makes firms worse off. It is easy to see that in this case $\mathbf{X}^{\mathrm{B}} \subseteq \mathbf{X}$—that is, that the set of implementable product-market action schedules is *reduced* by a ban, both because of the restriction $\partial x_i/\partial\tilde{\theta}_j = 0$ on $\mathbf{x}(\tilde{\boldsymbol{\theta}})$ imposed by a ban, and by the rise in

[12] Arguments have been raised for both consumer welfare and general welfare objectives (see Motta (2004)). We however focus on a consumer welfare objective for the simple reason that our analysis questions the usefulness of a ban on information exchange. Excluding firms' profits of the objective function makes the point against a ban strongest.

firms' minimal payoffs brought about by the ban. Consequently, if the antitrust authority can coordinate firms on its preferred equilibrium, a ban can only make it worse off in that it reduces the set of feasible choices.

To understand this more intuitively, suppose first that the stage-game equilibrium encompasses no information exchange, so that $\overline{\pi}_i^B = \overline{\pi}_i$, and consider the effect of a ban in terms of firms' payoffs as illustrated in Figure 2(a). Notice that the antitrust authority will want to select an equilibrium in which firms' profits are as low as possible, that is, where firms earn the stage-game profits of the respective regime:[13] Otherwise, the antitrust authority can always make consumers strictly better off by changing the product-market action schedule so as to lower prices or raise quantities for some $\boldsymbol{\theta}$ which occurs with positive probability. Thus, in terms of Figure 2(a), the authorities' preferred equilibrium under either regime will lie in the lower left-hand corner of the shaded areas. Here now it is important to recall, however, that points in the shaded area are attainable with various product-market action schedules $\mathbf{x}(\boldsymbol{\theta})$. Obviously, the additional degrees of freedom which information exchange affords on feasible schedules means that the antitrust authority can pick a (weakly) superior equilibrium *with* information exchange.

The same reasoning holds a fortiori if $\overline{\pi}_i^B > \overline{\pi}_i$: On top of the restriction $\partial x_i/\partial \tilde{\theta}_j = 0$ on implementable schedules, the ban now brings about a rise in firms' minimal profits, which makes a ban even less attractive from consumers' point of view.

Finally, however, if $\overline{\pi}_i^B < \overline{\pi}_i$, a ban on information exchange entails a non-trivial tradeoff between the loss implicit in the restriction $\partial x_i/\partial \tilde{\theta}_j = 0$, and the gain implicit in lowering firms' minimal payoffs. Bear in mind however that this case is only relevant if the equilibrium of the original stage game involves firms exchanging information.

In sum therefore, if the antitrust authority can coordinate firms on its preferred equilibrium and if the one-shot game equilibrium does *not* have firms exchange information, then a ban on information exchange will leave consumers weakly worse off (and strictly so in many cases) and leave firms unaffected. Intuitively, in a repeated setting with arbitrarily patient firms, authorities can let firms exchange information and pass all the gains from this coordination benefit on to consumers, by keeping firms' profits at the stage-game-equilibrium level.

[13] Strictly speaking, of course, $\mathrm{E}[\pi_i] = \overline{\pi}_i$ is not feasible for equilibria involving information exchange (as the 'punishment' then vanishes altogether), but any $\mathrm{E}[\pi_i] - \overline{\pi}_i > 0$ arbitrarily small is. To simplify arguments (and to circumvent the problem that, as a result of to this, there will typically *exist* no preferred equilibrium for the antitrust authority because the set of feasible equilibria is non-compact), we will here argue *as if* $\mathrm{E}[\pi_i] = \overline{\pi}_i$ were feasible.

3.2.2 Equilibrium Selection by the Firms

Next, and perhaps more interestingly, let us assume that, with or without a ban, *firms* can coordinate themselves on their preferred equilibrium. To again set this into perspective, notice that previous studies based on static models have essentially posited that a ban on information exchange, by assumption, is equivalent to restoring competition. However, provided that the firms engage in a long-term relationship, non-cooperative game theory suggests that many other equilibria which involve collusion but do not require information exchange are possible.

One way to operationalize the notion of the 'firms' preferred equilibrium' would be to assume that firms coordinate themselves on a *Pareto-efficient* equilibrium (graphically, in terms of Figure 1, that firms will coordinate themselves on the Pareto-efficient frontier to the north east). To keep things simple, we will here assume that firms can in fact coordinate themselves on the *joint-profit-maximizing* equilibrium on the Pareto-frontier—a stronger assumption which seems innocuous for symmetric settings.[14]

In terms of Figure 1, a ban on information exchange now has the obvious effect of (weakly) decreasing firms' joint profits. While, at first sight, this may appear to have an unambiguously positive effect on consumers, the ban on information exchange *does* however involve a certain loss in firms' ability to coordinate their product-market decisions. To the extent that this coordination benefits not only firms themselves but also consumers, a ban on information exchange may therefore leave consumers worse off even if it reduces firms' joint surplus.

To illustrate this point, consider the following example:

Example 4. Consider Example 1 and suppose that $b = 1$. The parameter $c \in [0,1]$ represents the degree of substitutability of the firms' goods (goods are perfect substitutes for $c = 1$ and independent-demand goods for $c = 0$), where $\theta \in \{\theta_L, \theta_H\}$, $\theta_L < \theta_H$, each with equal probability. Each firm i receives a signal $\tilde{\theta}_i \in \{L, H\}$, where $\Pr[\tilde{\theta}_i = H \mid \theta = \theta_H] = \Pr[\tilde{\theta}_i = L \mid \theta = \theta_L] = \phi > 1/2$,[15] which firms can decide to disclose or not prior to choosing their output q_i.

[14] Notice that the joint-profit maximizing product-market action plan under either regime will never be constrained by the respective stage-game equilibrium, so that distinctions as in Section 3.2.1 depending on whether $\overline{\pi}_i \gtreqless \overline{\pi}_i^B$ are not necessary.

[15] We assume $\Pr[\tilde{\theta}_i = H \mid \theta = \theta_H] = \Pr[\tilde{\theta}_i = L \mid \theta = \theta_L]$ so that the precision of the signal does not vary in the state. The requirement that each probability exceed $1/2$ represents both a requirement that signals be at least slightly informative, and a normalization (i.e., that receiving signal 'H' indeed raises the probability of $\theta = \theta_H$.)

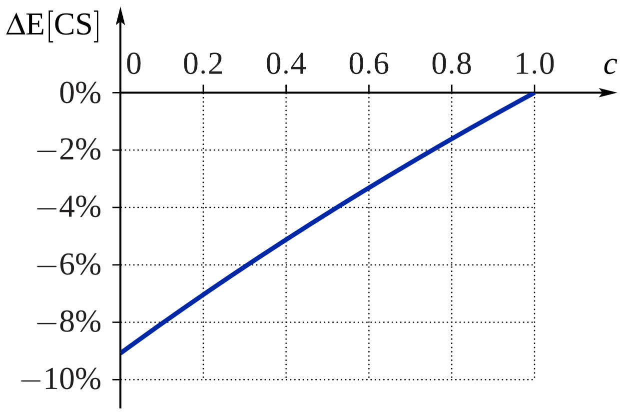


Figure 3: The Effect of a Ban on Information Exchange on Consumer Surplus (in%) in Example 4 for $\phi = 0.8$, $\theta_{\mathrm{H}} = 2$, $\theta_{\mathrm{L}} = 0$, when Firms Coordinate on Joint-Surplus-Maximizing Equilibrium.

Figure 3 shows the effect of a ban of information exchange on consumer surplus for this example (in percent, relative to consumer surplus with information exchange) for varying degree of substitutability c and specific values of the other parameters. As shown, a ban on information exchange always has a (weakly) *negative* impact on consumer surplus, and more strongly so the less substitutable goods are.

To develop an intuition for this, consider the polar cases in terms of the substitutability parameter c. For $c = 0$, firms' markets are independent, so firms are monopolists on their respective markets, but have mutually valuable information on the common demand parameter. The only effect of information exchange is then that each monopolist becomes better informed about his demand intercept, which is known to have a positive effect also on consumers in the case of a quantity-setting monopolist (cf. Vives and Kühn, 1994). At the other extreme, for $c = 1$, goods are perfect substitutes. As joint-surplus maximizers (and because costs are linear), firms will therefore only care about the *aggregate* quantity $x_1 + x_2$. Now, an important feature of the model at hand is that the joint-surplus maximizing aggregate quantity (i.e., the quantity that a monopolist in the market would produce) is *additively separable* in the two signals $\tilde{\theta}_1$ and $\tilde{\theta}_2$. Intuitively, this is because the update in the expected demand parameter θ caused by one signal being high rather than low is independent of the other signal's value—a property which, due to the linearity of the model, translates directly into a corresponding property of the joint-profit-maximizing aggregate quantity.[16] This property allows firms to implement the aggregate quantity which maximizes joint profits under information sharing even when there is *no* information sharing—simply by each firm producing more or less depending on its own signal. Thus, the aggregate output schedule $x_1(\boldsymbol{\theta})+x_2(\boldsymbol{\theta})$ will be *identical* with and without information sharing. Since goods are homogenous, consumers themselves will likewise care only about *aggregate* output, so that consumer surplus will be unaffected by whether information exchange is banned or not.

4 Information Exchange with Finitely Patient Firms

Section 3 has provided a natural counterpart to the usual one-shot-game analysis by considering the repeated game when players' limited patience is not an issue. In contrast, some of the previous literature (e.g. Clarke, 1983a) has argued that information exchange makes it 'easier' to collude in the sense that there may exist certain ranges for δ where collusion is *impossible* without information exchange. We see two shortcomings in those arguments, which our analysis seeks to address:

Exogenous Information Resolution: First, arguments have typically been based on a comparison of critical discount factors between models with and without asymmetric information—or in other words: arguments have been based on the effect of an *exogenous* resolution of asymmetric information on the discount factor required for collusion. In contrast, this section considers the impact of an *endogenous* resolution of informational asymmetries on the critical discount factor, which incorporates the possibility that inducing a firm to reveal its private information to its competitor may itself require some additional patience (as one would naturally expect in a model where information exchange is *not* an equilibrium of the stage game).

Comparing Different Collusive Outcomes: Second, the relevant critical discount factors with and without collusion usually support different collusive equilibrium outcomes. As such, it may be misleading to base policy advice on the fact that 'collusion is harder to sustain' in some regime A rather than B if the collusive

[16] For this property, it is important that the signal's precision be independent of the true state (see Footnote 15 above)—an assumption which, however, is common in the literature (cf. Gal-Or, 1985).

outcome supported by the critical discount factor in regime B in fact inflicts much less harm on consumers.

As far as the first point is concerned, our analysis below explicitly identifies the relevant additional constraint required for *endogenous* information exchange (a qualitative investigation concerning cases in which we should expect this additional constraint to be particularly relevant is left for future investigation). Regarding the second point, our analysis actually identifies an effect opposite from that discussed in the previous literature: Any *fixed* collusive equilibrium product-market action plan $\mathbf{x}(\tilde{\boldsymbol{\theta}})$ which can be implemented without information exchange (i.e., for some sufficiently high level of patience) is actually easier to implement without information exchange than with. Hence, in this specific sense, information exchange actually raises the critical discount factor.

To develop our results formally, notice that firms can deviate from a collusive equilibrium in two respects: They can deviate from the information disclosure action plan **d** prescribed by the action plan, and they can deviate from the product-market action plan $\mathbf{x}(\tilde{\boldsymbol{\theta}})$. In what follows, we examine these two incentive constraints in turn. Note beforehand that, as far as the 'ease of collusion' is concerned, each incentive constraint delivers a critical discount factor where, eventually, for *both* constraints to be satisfied, the *larger* critical delta is the relevant one for the overall equilibrium.

4.1 Deviations from the Information Exchange Agreement

When information exchange is not part of the stage-game Nash equilibrium, firms can earn an intra-period gain by withholding information. In an equilibrium with information exchange, this deviation incentive must be kept in check by future punishments, which requires a certain patience on firms' behalf.

To formulate this incentive constraint, let $\mathrm{E}_{\boldsymbol{\theta}|\tilde{\boldsymbol{\theta}}}[\pi_i^{\mathrm{IN}}((\tilde{\boldsymbol{\theta}});\boldsymbol{\theta})]$ denote firm i's expected profits in the equilibrium of the second-stage subgame after, in the first stage, firm i did *not* share information (N) with its competitor, but the other firm did (I). Then optimality of information sharing by firm i requires that

$$\mathrm{E}_{\boldsymbol{\theta}|\tilde{\boldsymbol{\theta}}}[\pi_i^{\mathrm{IN}}((\tilde{\boldsymbol{\theta}});\boldsymbol{\theta})] - \mathrm{E}_{\boldsymbol{\theta}|\tilde{\boldsymbol{\theta}}}[\pi_i(\mathbf{x}(\tilde{\boldsymbol{\theta}});\boldsymbol{\theta})] \leqslant \frac{\delta}{1-\delta}\Big[\mathrm{E}_{\boldsymbol{\theta}|\tilde{\boldsymbol{\theta}}}[\pi_i(\mathbf{x}(\tilde{\boldsymbol{\theta}});\boldsymbol{\theta})] - \overline{\pi}_i\Big], \tag{1}$$

where the left-hand side describes the intra-period gain from withholding information from the competitor (because an informed firm fares better in the stage-game equilibrium in which the other firm is uninformed rather than informed), and the right-hand side describes the future punishment implicit in a reversion to the stage-game equilibrium.

For any equilibrium *with* information sharing, condition (1) delivers a critical δ (that required to sustain a non-Nash-information-disclosure choice) which must then be compared with the critical δ required to sustain non-Nash product-market actions (analyzed in Section 4.2 below). Which of the two critical discount factors is larger (and thereby relevant) depends on the size of the intra-period gains from deviations in the product market relative to the size of the intra-period gains from withholding information.

A thorough analysis of the determinants of the relative magnitude of these deviation incentives will be the subject of future research. For the moment, we content ourselves by pointing out that any equilibrium *with* information exchange introduces an additional incentive constraint which ensures the *endogenous* revelation of information and that, if anything, this additional constraint *will* make collusion harder to sustain.

4.2 Deviations in the Product Market

Resuming our above discussion concerning the comparison of different collusive outcomes, as far as product-market actions are concerned, we should expect to find two separate effects of information exchange on the collusive outcome and the critical discount factor:

(i) First, information exchange enlarges the set of feasible product-market action plans $\mathbf{x}(\tilde{\boldsymbol{\theta}})$ simply because it permits conditioning each firm's action on the other's information. Through this very mechanical effect, information exchange may permit higher equilibrium payoffs than would be feasible without information exchange. Keeping punishment-strategies fixed (at Nash-equilibrium reversion), a higher equilibrium payoff always lowers the critical δ by raising the punishment implicit in Nash-equilibrium reversion. By this mechanical effect, collusion may be 'easier to sustain' under information exchange, simply because information exchange permits 'better' collusion (in the sense of making higher equilibrium payoffs technically feasible).

(ii) Second, however, for any product-market action plan $\mathbf{x}(\tilde{\boldsymbol{\theta}})$ which is feasible under *both* regimes (i.e., which does not require information exchange in the sense of Definition 2), we should expect equilibrium information exchange to *increase* the possible deviation gains, as a deviant firm can now tailor the timing of its deviation and the accompanying product-market action x_i to its competitor's information.

We show in this section (see Proposition 4 below) that, by the second effect alone, information exchange always *raises* the critical discount factor (i.e., using the literature's usual parlance, information exchange makes it harder to sustain collusion on a particular outcome). In other words, the only outcomes (i.e. product-market action plans $\mathbf{x}(\tilde{\boldsymbol{\theta}})$) which could possibly be 'easier' to collude on *with* information exchange are those which are not feasible without information exchange in the first place.

To put the conditioning on $\mathbf{x}(\tilde{\boldsymbol{\theta}})$ into perspective, note that any comparison of critical discount factors (with and without a ban on information exchange) raises difficulties similar to those in Section 3: Either regime hosts a wide variety of equilibria, and critical discount factors will vary between equilibria under either regime. Given this, a first approach would be to investigate the critical discount factor under the same equilibrium-selection criteria as in Section 3. *First*, if we suppose that firms always find it possible to coordinate on the surplus-maximizing equilibrium, then by the first ('mechanical') effect described above, we should expect that the equilibrium *without* a ban on information sharing indeed requires a lower critical discount factor. However, when deriving any kind of policy implication from this, it is important to bear in mind that, by the effect discussed in Section 3.2.2, consumers might actually well be left worse off by the allocation which results under a ban. In this case, any policy advice would need to take account of the trade-off between a decrease in the ease of collusion under a ban on the one-hand, and the less consumer-friendly product-market outcome caused by the ban. *Second*, if we suppose that the antitrust authority can coordinate firms on its preferred equilibrium, then it is easy to see that its preferred equilibrium *with* a ban (the repeated stage-game equilibrium) requires a discount factor of zero and that, as such, the critical discount factor *without* a ban will always be higher. In a similar vain however, when deriving a policy conclusion from this, this would need to be balanced against the larger degrees of freedom in choosing the product-market action plan under information exchange.

Eventually, however both of these approaches seem somewhat arbitrary given the large set of equilibria of the repeated game and the lack of any clear criteria for equilibrium selection. Consequently, our main result in this section again attempts to isolate the effect of information exchange by comparing critical discount factors *for any given product-market action schedule* $\mathbf{x}(\tilde{\boldsymbol{\theta}})$. We introduce the following notation: For any $\delta \in [0,1)$, let $\mathbf{X}^B(\delta)$ and $\mathbf{X}(\delta)$ denote the set of product-market action plans $\mathbf{x}(\tilde{\boldsymbol{\theta}})$ which, for this δ, are implementable in equilibrium *with* and *without* a ban on information exchange, respectively.[17] Consider any $\mathbf{x}(\tilde{\boldsymbol{\theta}})$ which, for *some* δ, are implementable both with a ban and without, i.e. $\mathbf{x}(\tilde{\boldsymbol{\theta}})$ such that for *some* δ, δ', $\mathbf{x}(\tilde{\boldsymbol{\theta}}) \in \mathbf{X}(\delta)$ and $\mathbf{x}(\tilde{\boldsymbol{\theta}}) \in \mathbf{X}^B(\delta')$. For simplicity, we assume that stage-game equilibrium involves no information exchange.

Now, for any δ, firm *i*'s incentive constraint in an *information-sharing* equilibrium which implements product-market action-schedule $\mathbf{x}(\tilde{\boldsymbol{\theta}})$ is

$$\max_{\tilde{\boldsymbol{\theta}} \in \tilde{\boldsymbol{\Theta}}} \Big\{ \max_{x_i} \mathrm{E}_{\boldsymbol{\theta}|\tilde{\boldsymbol{\theta}}}[\pi_i(x_i, x_j(\tilde{\boldsymbol{\theta}}); \boldsymbol{\theta})] - \mathrm{E}_{\boldsymbol{\theta}|\tilde{\boldsymbol{\theta}}}[\pi_i(\mathbf{x}(\tilde{\boldsymbol{\theta}}); \boldsymbol{\theta})] \Big\} \leqslant \tfrac{\delta}{1-\delta} \big(\mathrm{E}_{\boldsymbol{\theta}}[\pi_i(\mathbf{x}(\tilde{\boldsymbol{\theta}}); \boldsymbol{\theta})] - \overline{\pi}_i\big), \quad (2)$$

whereas that in a *non-information-sharing* equilibrium which implements $\mathbf{x}(\tilde{\boldsymbol{\theta}})$ reads

$$\max_{\theta_i \in \Theta_i} \Big\{ \max_{x_i} \mathrm{E}_{\boldsymbol{\theta}|\tilde{\theta}_i}[\pi_i(x_i, x_j(\tilde{\boldsymbol{\theta}}); \boldsymbol{\theta})] - \mathrm{E}_{\boldsymbol{\theta}|\tilde{\theta}_i}[\pi_i(\mathbf{x}(\tilde{\boldsymbol{\theta}}); \boldsymbol{\theta})] \Big\} \leqslant \tfrac{\delta}{1-\delta} \big(\mathrm{E}_{\boldsymbol{\theta}}[\pi_i(\mathbf{x}(\tilde{\boldsymbol{\theta}}); \boldsymbol{\theta})] - \overline{\pi}_i\big). \quad (3)$$

For given $\mathbf{x}(\tilde{\boldsymbol{\theta}})$ and δ, the right-hand sides of (2) and (3) are identical: The right-hand sides represent the compounded future 'punishment' for a deviation today, which is identical because (i) the same Nash-reversion trigger strategies are used in either case, and because (ii) firms always have identical beliefs about the future (regardless of whether they share information today or not). Thus, for given $\mathbf{x}(\tilde{\boldsymbol{\theta}})$, the left-hand sides of (2) and (3) capture the following two effects of information sharing on the critical discount factor: First, under information revelation, a deviating firm can tailor its optimal deviation action x_i not just to its own signal $\tilde{\theta}_i$ but to the *full* set of signals $\tilde{\boldsymbol{\theta}}$, which for certain realizations of θ_j enables it to reap a larger expected deviation payoff than if it is uncertain about θ_j. Second, with information sharing, it must be suboptimal for a firm to deviate not only *in expectation* over the other firm's possible signal, but for any

[17]Notice that this extends our previous notation in Section 3 in the sense that $\mathbf{X}(\delta) \xrightarrow{\delta \to 1} \mathbf{X}$ and $\mathbf{X}^B(\delta) \xrightarrow{\delta \to 1} \mathbf{X}^B$.

realization of the other's signal.

These two effects suggest that any given action plan $\mathbf{x}(\tilde{\boldsymbol{\theta}})$ which is feasible with as well as without information exchange is in fact easier to implement *without* information exchange. The following result, proven in the Appendix, confirms this intuition:

Proposition 4. *Suppose signals are perfect (i.e., $\tilde{\theta}_i = \theta_i$, $i = 1,2$).*[18] *Fix any $\delta \in [0,1)$ and consider any product-market action plan $\mathbf{x}(\tilde{\boldsymbol{\theta}}) \in \mathbf{X}(\delta)$ which* does not require information exchange *(i.e., a product-market plan which* is *implementable with information exchange, but which has $\partial x_i/\partial \tilde{\theta}_j = 0$, $i \neq j \in \{1,2\}$). Then $\mathbf{x}(\tilde{\boldsymbol{\theta}}) \in \mathbf{X}^B(\delta)$ so that, at this discount factor, the plan is also implementable without information exchange.*

Rephrased in terms of critical discount factors, Proposition 4 states that for any outcome $\mathbf{x}(\tilde{\boldsymbol{\theta}})$ which is in principle implementable with information exchange as well as without (for *some* δ), the exchange of information between firms actually makes collusion *harder* in the sense of (weakly) raising the critical discount factor.[19]

In other words, by Proposition 4, the only benefit of information exchange on the 'ease of collusion' is a purely technical one, in that it expands the set of available action plans $\mathbf{x}(\tilde{\boldsymbol{\theta}})$ to such with $\partial x_i/\partial \tilde{\theta}_j \neq 0$.

Remark. Proposition 4 can *not* be generalized to *payoff pairs* (π_1, π_2) in lieu of action plans $\mathbf{x}(\tilde{\boldsymbol{\theta}})$. I.e., it is *not* generally true that, for any $\delta \in [0,1)$, any payoff pair (π_1, π_2) which can be supported as equilibrium payoffs with information exchange can also be supported without. To see why, for any δ, let $\Pi(\delta) \equiv \pi(\mathbf{X}(\delta))$ and $\Pi^B(\delta) \equiv \pi(\mathbf{X}^B(\delta))$ denote the set of payoff pairs (π_1, π_2) which can be supported with and without information exchange, respectively, and let $\Pi(1) \equiv \lim_{\delta \to 1} \pi(\mathbf{X}(\delta))$ and $\Pi^B(1) \equiv \lim_{\delta \to 1} \pi(\mathbf{X}^B(\delta))$ denote the corresponding limits as $\delta \to 1$. From the Folk Theorem, we know that $\Pi^B(1) \subseteq \Pi(1)$. Now suppose that the claim were true, which means $\Pi(\delta) \subseteq \Pi^B(\delta)$ for all $\delta \in [0,1)$. Since $\Pi^B(\delta) \subseteq \Pi^B(1)$, this would mean that all points in the shaded area below (formally, points in the set $\Pi(1) \setminus \Pi^B(1)$) would be

[18] To the best of our knowledge, the assumption that signals are perfect is not crucial. It is only invoked here to keep expressions simple by avoiding having to wrap a $\mathrm{E}_{\boldsymbol{\theta}|\tilde{\boldsymbol{\theta}}}[\cdot]$ around all the terms in the proof of Proposition 4.

[19] Concerning the *weakness* of the result, it is easy to see both from the above intuition and the proof in the Appendix that the inequalities which lead to the result will actually be *strict* in any but trivial environments (more specifically: environments in which one firm's deviation incentives are actually *independent* of the other firm's information), so that information exchange will actually make collusion on the respective outcomes *strictly* harder in most cases.

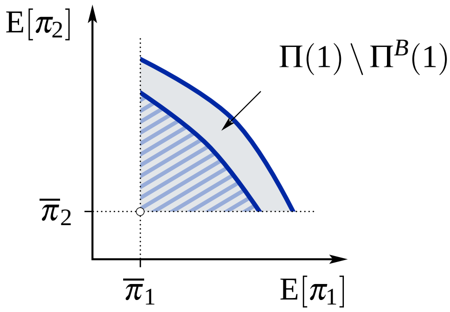


Figure 4: Illustration why Proposition 4 Cannot be Generalized to Payoff Pairs (π_1, π_2).

contained *only* in $\Pi(1)$ but not in $\Pi(\delta)$, $\delta < 1$—a contradiction to the construction of $\Pi(1)$ as a limit in cases such as the one depicted in Figure 4.

5 Conclusion

This paper formalizes the idea that information sharing, like collusive activity, is inherently dynamic. We use this framework to examine how banning information exchange between repeatedly interacting oligopolists affects consumer surplus. While previous literature has usually posited a more or less ad hoc link between information sharing and collusion, we isolate the effect of the exchange of *prospective* information from the accompanying level of collusion. We do this by accounting for the fact that, even without exchanging information, firms can tacitly collude, and that, even with the exchange of information, firms may act very close to competitively.

We have three main results: First, in the limit, if firms are arbitrarily patient, they can sustain any possible degree of product-market collusion. We find that all the combinations sustainable without information exchange can also be implemented with information exchange. Hence, if firms are arbitrarily patient, the set of possible equilibria of the repeated game displays absolutely no correlation between information exchange and degree of collusion.

Second, again in the limit, a ban on information sharing pushes colluding firms which also communicate to switch to tacit collusion. This switch can cause a loss to consumers through the firms' acting under more uncertainty, but, at the same time, provided that it reduces the degree of collusion, may also involve a gain. The size of the latter effect depends on the degree of collusion the firms can sustain in the absence of information sharing. Since the firms can tacitly collude, a ban on information exchange does not necessarily restore competition, and the gain in consumer surplus due to a lower degree of collusion may be too small to outweigh the loss due to firms facing higher uncertainty.

Third, for finitely patient firms, we find that information sharing may actually decrease cartel stability. One the one hand, this is due to the fact that better information can strengthen the firms' deviation payoffs by allowing them to more accurately tailor their deviations to the prevailing market conditions. On the other hand, inducing firms to share information itself requires additional patience.

Appendix A. Proofs

Proof of Proposition 4. From the discussion preceding Proposition 4, it follows that we can establish the claim by showing that, if

$$\max_{x_i} \pi_i(x_i, x_j(\boldsymbol{\theta}); \boldsymbol{\theta}) - \pi_i(\mathbf{x}(\boldsymbol{\theta}); \boldsymbol{\theta}) \leqslant A, \quad \text{for all } \boldsymbol{\theta} \in \boldsymbol{\Theta} \tag{A.1}$$

and for $A \equiv \frac{\delta}{1-\delta}\left(\pi_i(\mathbf{x}(\boldsymbol{\theta}); \boldsymbol{\theta}) - \overline{\pi}_i\right)$, then

$$\max_{x_i} \mathrm{E}_{\theta_j}[\pi_i(x_i, x_j(\boldsymbol{\theta}); \boldsymbol{\theta})] - \mathrm{E}_{\theta_j}[\pi_i(\mathbf{x}(\boldsymbol{\theta}); \boldsymbol{\theta})] \leqslant A, \quad \text{for all } \theta_i \in \Theta_i. \tag{A.2}$$

Now assume that (A.1) holds. Since by presumption, the inequality in (A.1) holds for *all* $\theta_j \in \Theta_j$, taking expectations over θ_j delivers

$$\mathrm{E}_{\theta_j}[\max_{x_i} \pi_i(x_i, x_j(\boldsymbol{\theta}); \boldsymbol{\theta})] - \mathrm{E}_{\theta_j}[\pi_i(\mathbf{x}(\boldsymbol{\theta}); \boldsymbol{\theta})] \leqslant A, \quad \text{for all } \theta_i \in \Theta_i. \tag{A.3}$$

Now fix any $\theta_i \in \Theta_i$ and let $\tilde{x}_i$ denote any x_i which maximizes the first term on the left-hand side of (A.3) (i.e., let $\tilde{x}_i \in \arg\max_{x_i} \mathrm{E}_{\theta_j}[\pi_i(x_i, x_j(\boldsymbol{\theta}); \boldsymbol{\theta})]$). Then

$$\max_{x_i} \mathrm{E}_{\theta_j}[\pi_i(x_i, x_j(\boldsymbol{\theta}); \boldsymbol{\theta})] = \mathrm{E}_{\theta_j}[\pi_i(\tilde{x}_i, x_j(\boldsymbol{\theta}); \boldsymbol{\theta})] \leqslant \mathrm{E}_{\theta_j}[\max_{x_i} \pi_i(x_i, x_j(\boldsymbol{\theta}); \boldsymbol{\theta})], \tag{A.4}$$

where the equality follows from the definition of $\tilde{x}_i$, and the inequality because setting $x_i = \tilde{x}_i$ for all θ_j is always an option in the maximization problem on the rightmost side. Thus,

$$\max_{x_i} \mathrm{E}_{\theta_j}[\pi_i(x_i, x_j(\boldsymbol{\theta}); \boldsymbol{\theta})] \leqslant \mathrm{E}_{\theta_j}[\max_{x_i} \pi_i(x_i, x_j(\boldsymbol{\theta}); \boldsymbol{\theta})], \quad \text{for all } \theta_i \in \Theta_i. \tag{A.5}$$

Combining (A.5) with (A.3) implies (A.2), as was to be shown. □

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