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A THEORY OF RING LEADERS**

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ABSTRACT

Asymmetric Cartels - a Theory of Ring Leaders*

Many convicted cartels have a leader, which is substantially larger than its rivals. In a setting where firms face indivisible costs of collusion, we show that: (i) firms may have an incentive to merge so as to create asymmetric market structures since this enables the merged firm to cover the indivisible cost associated with cartel leadership; and (ii) forbidding mergers leading to symmetric market structures can induce mergers leading to asymmetric market structures with a higher risk of collusion. Thus, these results have implications for the practice of the current EU and US merger policies.

JEL Classification: D43 and L41
Keywords: cartels, collusion, cost asymmetries, merger policy and ring leader

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1 Introduction

The detection and prosecution of cartels is one of the main priorities of competition authorities in most jurisdictions, including the European Union and the USA. In many convicted cartels, the courts have found that one of the cartel members played a significant role for the existence of the cartel, i.e. it was a cartel or "ring" leader. For instance, in 10 out of 43 cartels that were fined by the European Commission during the period 2002 to 2007, i.e. in approximately 23 percent of the cases, a ring leader was explicitly identified. Another empirical regularity is that there is often a noticeable size difference (as measured by market shares) between the largest and the second or third largest firm in real cartels. In approximately 38 % of the 43 European cartel cases between 2002 and 2007, the size of the largest firm exceeds the size of second largest firm by at least 50 %. Moreover, in about three quarters of the cases, the size of the largest firm exceeds that of the third largest firm by more than 50 % (for further details, see Table 1).[1]

Decile	Next Largest	Third Largest
1st	33%	6%
2nd	48%	26%
3rd	61%	33%
4th	69%	37%
5th	80%	44%
6th	97%	52%
7th	100%	63%
8th	100%	68%
9th	100%	77%
Max	100%	90%
Mean	75%	45%

Table 1: The Relative Size of the 3 Largest Members of European Cartels (Relative Size Compared to Largest Firm)

A similar pattern emerges if one studies mergers and acquisitions that have been investigated in detail by the European Commission based on concerns that they may result in "coordinated effects", i.e. an increased risk of

[1] Authors' calculations based on 43 cartel cases in the period 2002-2007.

collusion. In approximately 35 % of the 21 phase II investigations of mergers possibly resulting in coordinated effects, the size of the largest firm exceeds the size of the second largest firm by at least 50 %. Moreover, in about 90% of the cases, the size of the largest firm exceeds that of the third largest firm by more than 50 % (for further details, see Table 2).[2]

Decile	**Next Largest**	**Third Largest**
1st	12%	3%
2nd	33%	7%
3rd	52%	10%
4th	75%	17%
5th	83%	30%
6th	86%	39%
7th	93%	52%
8th	100%	56%
9th	100%	67%
Max	100%	78%
Mean	70%	32%

Table 2: Firm Size in European Coordinated Effects Merger Cases (Relative Size Compared to the Largest Firm)

These observations raise the question of why so many cartels have a ring leader and why the leading firm is so frequently substantially larger than other firms in a collusive market.

We present one possible theoretical explanation for this phenomenon. Our starting point is that the possibility of sharing the costs associated with running a cartel is limited. For instance, the cost of protecting the cartel by buying out potential entrants typically falls on the acquiring firm, thus permitting coconspirators to free-ride on the investment. Moreover, it is less costly to have only a few firms administering and monitoring the price behavior of the colluding firms.[3] In order to focus on this aspect, we assume there to be an indivisible cost associated with collusion.

[2] Authors' calculations based on 21 EC merger cases in the period 1993-2007.

[3] Harrington (2006, pp. 49-51) provides some evidence that in real world cartels, the tasks of monitoring sales volumes and auditing sales volumes (to solve problems of misreporting sales volumes) are usually carried out by a single cartel member.

Previous contributions to the literature have stressed that symmetry, absent indivisible costs associated with cartels, is a factor conducive to collusion.[4] This literature shows that small (more inefficient) firms gain less from the collusive agreement with respect to their optimal deviation strategies. Moreover, a large firm is proportionally more penalized in the punishment phase and therefore has a greater incentive to deviate from punishment. These factors suggest that collusion is easier to sustain when firms are symmetric.

We add to this literature by showing that if there is an indivisible cost associated with collusion, a medium asymmetric market structure might be more conducive to collusion since it balances the incentive to stay in the cartel with the need to cover the cartel leader's indivisible costs.

Using a standard repeated game oligopoly framework, our first main result is that there are levels of the indivisible cost of collusion such that: (*i*) firms do not collude when asymmetries are small; (*ii*) firms do collude when asymmetries are moderate; and (*iii*) firms do not collude when asymmetries are large.[5] On the one hand, firms cannot be too asymmetric, since a large asymmetry gives the smallest firm in the collusive agreement a strong incentive to deviate from the collusive conduct (the smallest firm is the one with the highest potential of stealing the business of its rivals). On the other hand, firms must be sufficiently asymmetric or else the largest firm (the ring leader) would lack the incentive to cover the indivisible cost of collusion. In other words, an indivisible cost of collusion introduces a second constraint that must be met for collusion to be sustainable.

We then proceed to analyze the equilibrium in an endogenous merger model.[6] In this theoretical framework, we are able to show that firms may have an incentive to merge so as to create asymmetric market structures conducive to collusion, i.e. market structures where one firm could cover the indivisible cost associated with being the cartel leader. More specifically, we show that this result holds in a differentiated products Bertrand model

[4] See Compte, Jenny and Rey (2002) and Vasconcelos (2005) and earlier contributions by Verboven (1997) and Rothschild (1999).

[5] In their survey article, Levenstein and Suslow (2006, p. 47) report that cost-asymmetries have ambiguous effects on collusive stability.

[6] We use the model by Horn and Persson (2001a). This model has, for instance, been applied to study how the pattern of domestic and cross-border mergers depends on trade costs by Horn and Persson (2001b), and the incentives for the formation of domestic and cross-border mergers in unionized oligopoly by Lommerud, Sorgard and Straume (2006).

(henceforth DPB model) à la Singh and Vives (1984) for a cartel that (*i*) maximizes joint profits, or (*ii*) imposes an equal increase in prices for all products sold by the cartel members.

We then turn to the implications for merger policy. Symmetry of firms in an industry is a factor that has attracted some attention in merger reviews by antitrust authorities on both sides of the Atlantic. This interest stems from the fact that firm and product homogeneity may potentially be conducive to coordinated effects in an oligopolistic market. The European Commission, for instance, notes in the Guidelines on the assessment of horizontal mergers that "[f]irms may find it easier to reach a common understanding on the terms of coordination if they are relatively symmetric".[7] Similarly, the US Horizontal Merger Guidelines state that "reaching terms of coordination may be facilitated by product or firm homogeneity".[8] The relevance of this factor is, for instance, illustrated by the *Baby-food case*, where the Federal Trade Commission argued that the proposed merger would make the two remaining suppliers' cost structures more similar and which allow these rivals to "arrive at a mutually advantageous detente".[9]

Our second main result, however, shows that a policy that blocks mergers leading to a symmetric industry structure may be counterproductive. The adoption of such a policy can induce firms to choose mergers leading to asymmetric market structures with higher production costs and a lower

[7] The Guidelines make an explicit reference to the Gencor-Lonrho merger (Case/M 619) and the Nestlé-Perrier merger (Comp/M 190). In the latter case, the Commission found that Nestlé/Perrier and BSN would be jointly dominant in the French market for bottled water and, more specifically, that "[a]fter the merger, there would remain two national suppliers on the market which would have similar capacities and similar market shares (symmetric duopoly) ... Given this equally important stake in the market and their high sales volumes, any aggressive competitive action by one would have a direct and significant impact on the activity of the other supplier and most certainly provoke strong reactions with the result that such actions could considerably harm both suppliers in their profitability without improving their sales volumes. Their reciprocal dependency thus creates a strong common interest and incentive to maximize profits by engaging in anti-competitive parallel behavior. This situation of common interests is further reinforced by the fact that Nestlé and BSN are similar in size and nature, are both active in the wider food industry and already cooperate in some sectors of that industry."

[8] Horizontal Merger Guidelines, U.S. Department of Justice and the Federal Trade Commission, Issued: April 2, 1992, Available at http://www.usdoj.gov/atr/public/guidelines/horiz_book/hmg1.html

[9] FTC ./. H.J. Heinz Company, Public Version of Commission Reply Brief, January 17, 2001, Downloaded from http://www.ftc.gov/os/2001/01/heinze.pdf

aggregated producer and consumer surplus. If a merger induces a symmetric industry structure, the large (efficient) firm may not find it profitable to bear the indivisible cost of collusion after the merger, thus ruling out collusion possibilities. But if an "anti-symmetry" merger policy is being adopted, it may well happen that equilibrium mergers induce an industry structure where firms are moderately asymmetric, creating the most favorable conditions for collusion to arise. Moreover, for some parameter values, the gains from successful collusion which are obtained in this asymmetric industry structure are so high that they will more than compensate for the fact that one of the colluding firms has high production costs. Consequently, by forbidding a merger leading to a symmetric industry structure, competition authorities may end up with a merger that does not only create higher production costs, but also facilitates collusion.

Next, we endogenize the indivisible cost of collusion by introducing a potential entrant whose entry would lead to a cartel breakdown. When this is the case, a cartel member may prevent entry by conducting a buyout acquisition of the potential entrant. However, this buyout will be costly for the acquirer and could thus be viewed as an endogenous indivisible cost which must be incurred so as to protect the cartel. It follows that the cartel member undertaking this buyout needs to earn sufficiently high profits in the subsequent cartel interaction and thus, the analysis and the mechanisms described above hold. It then follows that the lower are the exogenous entry barriers, the more asymmetric must the market structure be to sustain collusion, since entry-deterring take-overs to protect the cartel then become more costly. Consequently, an empirical prediction of the model is that we should observe relatively more asymmetric cartels in markets with low exogenous entry barriers.

Key to the result described above is that the rule determining the collusive outcome must have the property that the large (efficient) firm benefits sufficiently more from collusion when industry asymmetries increase, which is the case for both the joint profit maximizing cartel rule, and the equal price increasing cartel rule. In contrast, we show that if the rule determining the collusive outcome instead has the property that the large (efficient) firms' gains from collusion do not increase in asymmetry, then asymmetries between firms hurt collusion possibilities even more when an indivisible cost of collusion is present. For collusion to arise in this case, firms cannot be too asymmetric since the large (efficient) firm will then have no incentives to cover the indivisible cost.[10] This is shown to hold in the DPB model under a constant market share cartel behavior rule.[11]

Strategic acquisitions by a ringleader to protect a cartel seem to have been important in several cartel cases. One example is the *pre-insulated pipe cartel* in Europe in the 1990s, subsequently referred to as the "ABB case", which can briefly be described as follows.[12]

In 1987, just before the merger with ASEA, Brown Boveri Company embarked on a strategic program of acquiring district heating pipe producers across Europe. According to the European Commission: "The organization of the cartel represented a strategic plan by ABB to control the district heating industry ... It is abundantly clear that ABB systematically used its economic power and resources as a major multinational company to reinforce the effectiveness of the cartel and to ensure that other undertakings complied with its wishes ... The gravity of the infringement is aggravated in ABB's case by the following factors: ABB's role as the ringleader and instigator of the cartel and its bringing pressure on other undertakings to persuade them to enter the cartel."[13]

Moreover, ABB took the bulk of the costs of running the cartel. In particular, in the situation where Powerpipe, a firm outside the cartel, tried to expand its activities, ABB used large resources trying to eliminate the maverick from the market.[14] This predatory activity was multi-dimensional and costly as indicated by the following quote in §§91-92 of the EC Decision: "Numerous passages in ABB strategy documents during this period covered by this Decision refer to plans to force Powerpipe into bankruptcy... In 1993 ABB embarked on a systematic campaign of luring away key employees of Powerpipe, including its then managing director, by offering the salaries and conditions which were apparently exceptional in the industry."

We try to capture some of these aspects in our theoretical analysis. In particular, we take the costs of maintaining and protecting a cartel seriously and show that indivisible costs associated with cartel behavior have important implications for the relationship between symmetry and collusion. We

[10] A small inefficient firm will have an even weaker incentive to cover the indivisible cost.

[11] This rule has been used in several cartels in practice (see Harrington (2006)).

[12] Case No IV/35.691/E-4: Pre-Insulated Pipe Cartel, *Official Journal of the European Communities*, L 24/1, 30.1.1999.

[13] §169 and §171 in the Decision.

[14] As pointed out by the Commission, "Its systematic orchestration of retaliatory measures against Powerpipe, aimed at its elimination."

argue that the existence of indivisible costs of collusion is a possible explanation for the empirical observation that many cartels appear to arise in asymmetric markets.

The paper continues as follows. The model is spelled out in Section 2. Section 2.1 studies the collusion pattern when firms are asymmetric and one firm faces an indivisible cost of collusion, while Section 2.2 shows that an anti-symmetry merger policy can be counterproductive. Section 3 provides an extension of the basic model where the indivisible cost of cartelization is endogenized. Finally, Section 4 concludes.

2 The model

We consider a market with three initial firms, denoted $1, 2$ and 3. The firms play an infinitely repeated game. In period 0, there is a merger formation game in which a merger between two of the firms is possible.[15] Then, from period 1 onwards, the firms resulting from the merger formation process play a standard repeated oligopoly game. The game is solved backwards in the usual fashion.

Pre-merger, the constant variable costs of firms 1, 2 and 3 are $c_1 = c > 0$, $c_2 = 0$, and $c_3 = 0$, respectively. Post merger, there will be two firms active in the market, where the merged firm's variable cost c_m is equal to the lowest variable cost of the participating firms (i.e. $\min(c_i, c_j) = 0$ for $i \neq j$), and the non-merged firm's variable cost is denoted c_n. Firm i's per-period profit is denoted $\pi_i^t\left(x_i^t, x_{-i}^t, c_i, c_{-i}\right)$, where x_i^t is firm i's price in period t. The partial derivative of the profit with respect to the firm's own marginal cost is assumed to be negative, i.e. $\frac{\partial \pi_i^t\left(x_i^t, x_{-i}^t, c_i, c_{-i}\right)}{\partial c_i} < 0$, while the partial derivative with respect to a competitor's marginal cost is positive, i.e. $\frac{\partial \pi_i^t\left(x_i^t, x_{-i}^t, c_i, c_{-i}\right)}{\partial c_{-i}} > 0$.

2.1 The last stage: A repeated oligopoly game

We start our analysis in the last stage and identify conditions for sustainable collusion. Time is denoted by $t = 0, ..., \infty$. At the beginning of the last

[15] To explain why the merger opportunity arises now and not before is outside the scope of this paper. However, the merger could be triggered by a cost shock, for instance.

stage, the present value of firm i's profit is

$$\Pi_i = \sum_{t=0}^{\infty} \delta^t \cdot \pi_i^t \left(x_i^t, x_{-i}^t, c_i, c_{-i}\right), \tag{1}$$

where $\delta \in (0,1)$ is the common discount factor.

Firms will try to collude, which may or may not be possible in the repeated game. As argued in the introduction, there is some cost of collusion that is indivisible and not easily shared. To highlight this feature of collusion, we make the following assumption:

Assumption 1 Firm m must incur a fixed indivisible cost f per period of collusion.

Furthermore, we assume that a deviation is detected instantaneously and firms employ standard grim-trigger strategies (Friedman, 1971) to sustain the collusive agreement, i.e., whenever one firm deviates from the collusive norm, the other firm will play non-cooperatively in the next period and forever after.

Collusion is said to be sustainable if, for each firm i ($i = m, n$), the potential short-run gains from cheating are no greater than the present value of expected future losses that are due to the subsequent punishment. This trade-off is captured by the analysis of each firm's incentive compatibility constraint (ICC). The ICC for firm m is given by:

$$\sum_{t=0}^{\infty} \left[\pi_m^C \left(x_m^C, x_n^C, c_m, c_n\right) - f\right] \cdot \delta^t \geq \pi_m \left(x_m^* \left(x_n^C\right), x_n^C, c_m, c_n\right) + \sum_{t=1}^{\infty} \pi_m \left(x_m^B, x_n^B, c_m, c_n\right) \delta^t \tag{2}$$

and, correspondingly, for firm n by

$$\sum_{t=0}^{\infty} \pi_n^C \left(x_n^C, x_m^C, c_n, c_m\right) \delta^t \geq \pi_n \left(x_n^* \left(x_m^C\right), x_m^C, c_n, c_m\right) + \sum_{t=1}^{\infty} \pi_n \left(x_n^B, x_m^B, c_n, c_m\right) \delta^t, \tag{3}$$

where $x_i^*(\bullet)$ represents firm i's reaction function, x_i^C denotes firm i's collusive price and x_i^B the Bertrand-Nash equilibrium price.

Rewriting the ICC (2) of firm m (which bears the indivisible cost), we can solve for the critical indivisible cost $\overline{f}$, which is the greatest indivisible cost that the firm can incur and still find it profitable to stay in the cartel:

$$\overline{f}(c_n,\delta) = \pi_m^C\left(x_m^C, x_n^C, c_m, c_n\right) - (1-\delta)\,\pi_m\left(x_m^*\left(x_n^C\right), x_n^C, c_m, c_n\right) - \delta\pi_m\left(x_m^B, x_n^B, c_m, c_n\right), \tag{4}$$

which is a continuous function in the marginal cost of firm n, and the discount factor (δ). Recall that the marginal cost of firm m is zero.

To focus on the effect of the indivisible cost of collusion in the symmetric **case,** we make the following assumption:

Assumption 2 Firms are sufficiently patient, i.e. δ is sufficiently high, for collusion to be sustainable when both firms have zero production costs, $c_n = c_m = 0$, and the indivisible fixed cost of collusion is zero, $f = 0$.

For simplicity, we also assume that:

Assumption 3 There exists a unique c_n (denoted c^*) for which the ICC of firm n, i.e. (3), binds with equality.

In the following, we will use a Differentiated Product Bertrand (DPB) model *à la* Singh and Vives (1984) to derive specific results. The DPB model is presented in the Appendix. More specifically, it can be shown that Assumption 3 holds in the DPB model and in other asymmetric collusion models in the literature, such as Vasconcelos (2005) and Compte *et al.* (2002).

The equilibrium collusion pattern is illustrated in Figure 1, where the variable cost of firm n, c_n, is depicted on the x-axis and the indivisible fixed cost of collusion f is depicted on the y-axis, and where δ is fixed.

The symmetric market structure. Let us first address the case where firm n faces a zero variable production cost (recall that firm m is assumed to have a zero variable production cost). $ICC - s$ then depicts the indivisible fixed cost at which firm m's ICC (2) binds when firm n also faces a zero production cost. We refer to this as f', where $f' \equiv \overline{f}(0,\delta)$ (see eq. (4)). This curve is horizontal since, by assumption, both firms have a marginal cost of production which is zero. It follows that collusion is sustainable in the symmetric market if $f < f'$.

The asymmetric market structure. Let us now turn to the case in which firm n has a positive production cost, $c_n > 0$. In this case, $ICC - n$ shows the production cost c_n at which firm n's ICC (3) binds. This curve is vertical since firm n is assumed not to pay the per-period fixed indivisible cost. In addition, Assumptions 2 and 3 imply that ICC (3) holds only if cost asymmetries are sufficiently low, i.e., if $c_n < c^*$.

Finally, $ICC - m$ shows combinations of c_n and f for which firm m's ICC (2) binds. At $c_n = 0$, this curve obviously coincides with the curve $ICC - s$ (i.e. firm m's ICC under symmetry).

The slope of the curve $ICC - m$ is unfortunately ambiguous. In order to illustrate our first result, we make use of the following assumption, which implies that the $ICC - m$ curve is upward sloping at $c_n = 0$ and never below $ICC - s$:

Assumption 4a $\overline{f}(c_n, \delta)$ is weakly increasing in c_n and $\left.\frac{\partial \overline{f}(c_n,\delta)}{\partial c_n} > 0\right|_{c_n=0}$.

Assumption 4a holds in the DPB model under several assumptions of how firms share profits in the collusive phase:[16] (i) a joint profit-maximizing (JPM) cartel, where firms choose prices or quantities to maximize joint profits, or (ii) an equal price increase cartel, where each firm increases its price by an equal amount from the non-collusive equilibrium price.

Clearly, there will be collusion in this asymmetric market structure if and only if we are below the $ICC - m$ curve and to the left of the $ICC - n$ curve. So, we can now characterize the equilibrium collusion pattern under Assumptions 1-3 and 4a. This is done in Figure 1, where $\{C, *\}$ indicates that collusion can be sustained in the symmetric market structure, but not in the asymmetric market structure, $\{*, C\}$ indicates that collusion cannot be sustained in the symmetric market structure but can be sustained in the asymmetric market structure, etc.

We specifically note that there exist parameter values in the DPB model under the joint profit-maximizing rule or the equal price increase rule, such that Figure 1 is valid. We derive Figure 1 from the DPB model in Appendices B1 and C1. Now, using Figure 1, we have the following result:

Proposition 1 *Under Assumptions 1-3 and 4a, and at a fixed indivisible cost so high that no collusion can be sustained in the symmetric case ($f > f'$), there exists a fixed indivisible cost such that* (i) *firms do not collude for low asymmetries;* (ii) *firms do collude for intermediate asymmetries; and* (iii) *firms do not collude for large asymmetries.*

[16] See Appendices B1 and C1.

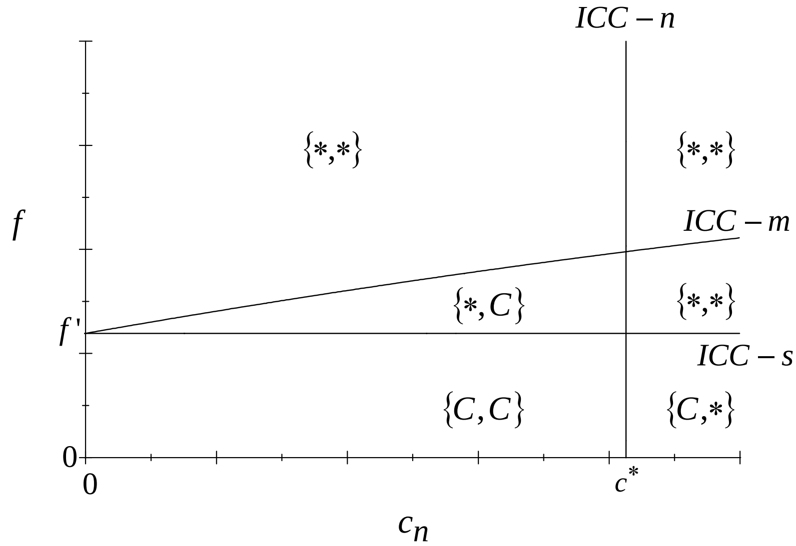

Figure 1: Equilibrium Collusion Pattern: ICC-m upward sloping

Proof. Let $f = f' + \epsilon$ (i.e. ICC-s does not hold), where ϵ is arbitrarily small and positive, and let c' denote the value of c_n for which the ICC-m binds with equality at $f = f' + \epsilon$. Then, there exist (i) $c_i < c'$ such that ICC-m does not hold; (ii) $c_{ii} \in (c', c^*)$ such that ICC-m and ICC-n hold simultaneously; and (iii) $c_{iii} > c^*$ such that ICC-n does not hold. ■

This result thus shows that there exist levels for the fixed indivisible cost of collusion such that (i) firms do not collude when asymmetries are small; (ii) firms do collude when asymmetries are moderate; and (iii) firms do not collude when asymmetries are large. The intuition is straightforward. For collusion to arise, firms cannot be too symmetric since the largest (most efficient) firm will then not have the incentive to cover the fixed indivisible cost of collusion.[17] On the other hand, firms cannot be too asymmetric either, for if there are strong asymmetries, the smallest firm in the collusive agreement will have strong incentives to deviate from the collusive conduct and steal the business of its rival.

[17] Remember that under the joint profit-maximizing or the equal price increase rule, this firm benefits less from cartel formation when the industry is more symmetric.

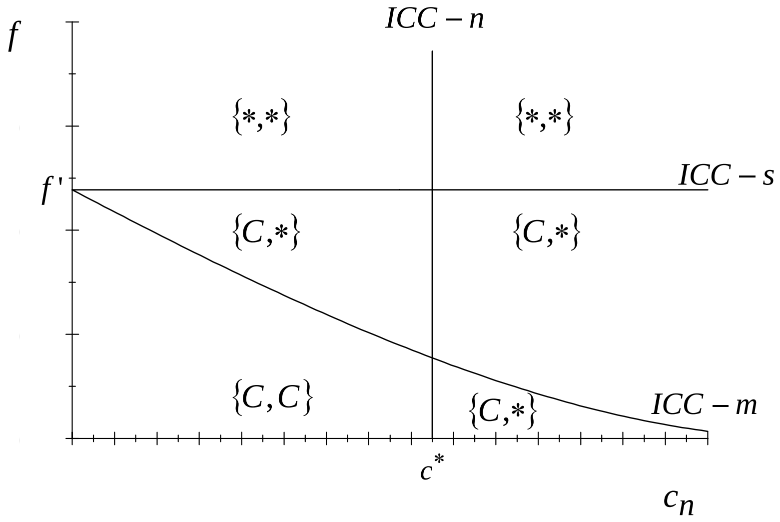

Figure 2: Equilibrium Collusion Pattern: ICC-m downward sloping.

To illustrate our second result, we now make use of the following assumption, which implies that the ICC-m curve is downward sloping at $c_n = 0$ and is never above ICC-s:

Assumption 4b $\overline{f}\,(c_n, \delta)$ is weakly decreasing in c_n and $\frac{\partial \overline{f}(c_n,\delta)}{\partial c_n} < 0\Big|_{c_n=0}$.

Assumption 4b holds, for instance, in the DPB model under the constant market shares rule (see Appendix C2), where firms increase prices (reduce quantities) keeping market shares constant (i.e., equal to the market shares in the Bertrand-Nash equilibrium). We can now characterize the equilibrium collusion pattern under Assumptions 1-3 and 4b. This is illustrated in Figure 2.[18] We can now derive the following result:

Proposition 2 *Under Assumptions 1-3 and 4b, and at such a low fixed indivisible cost that collusion can be sustained in the symmetric case ($f < f'$), there exist levels for the fixed indivisible cost such that (i) firms collude for small asymmetries; and (ii) firms do not collude for large asymmetries.*

[18] Appendix C2 also demonstrates that there exist parameter values in the DPB model, under the constant market shares rule, for which Figure 2 is valid.

Proof. Let $f = f' - \varepsilon$, where ε is arbitrarily small and positive, and let $\widetilde{c}'$ denote the value of c_n for which the ICC-m binds with equality at $f = f' - \varepsilon$. Then, there exists (i) $\widetilde{c}_i < \widetilde{c}'$ such that ICC-m and ICC-n hold; and (ii) $\widetilde{c}_{ii} > \widetilde{c}'$ such that ICC-m does not hold. ■

This result thus shows that there exist levels for the fixed indivisible cost of collusion such that (i) firms collude when asymmetries are minimal but do not collude when asymmetries are larger. For collusion to arise, firms cannot be too asymmetric, otherwise the largest (most efficient) firm will not have the incentive to cover the fixed indivisible cost of collusion, since it benefits less from the cartel being formed under the constant market share rule. Moreover, firms cannot be too asymmetric for another reason. If there are strong asymmetries, the smallest firm in the collusive agreement will have strong incentives to deviate from the collusive conduct and steal the business from its rival.[19]

2.2 The first stage: Merger formation

We next proceed to analyze the incentives for mergers prior to the repeated game played in the last stage. In the merger formation game, firms will take into account the equilibrium outcome under different market structures in the last stage. Depending on what merger takes place in the first stage, collusion may or may not arise in the last stage, which is potentially a motive for policy intervention.

As demonstrated by the analysis below, however, efficiency-enhancing regulatory intervention could be difficult. Blocking the most desirable merger from the firms' perspective may result in a market structure that is more, not less, conducive to coordination. A poorly designed merger policy can thus be counterproductive.

In order to determine the merger pattern, we make use of an endogenous merger model developed by Horn and Persson (2001a), where merger formation is treated as a cooperative game of coalition formation. The merger model has three basic components: (i) a specification of the owners determining whether one ownership structure M^i dominates another structure; (ii) a criterion for determining when these owners prefer the former structure to the latter; and (iii) a stability (solution) criterion that selects the ownership

[19] Note that it can be shown that the non-merged (inefficient) firms will have a lower incentive to cover the fixed cost than the merged (efficient) firm in these examples.

structures seen as solutions to the merger formation game on basis of all pairwise dominance rankings.

The dominance relation is such that for some market structure M^j to dominate or block another structure M^i, all owners involved in forming and breaking up mergers between the two structures in some sense prefer the dominating structure to the other structure. Which owners are then able to influence whether M^j dominates M^i? Owners belonging to identical coalitions in the two structures cannot affect whether M^j will be formed instead of M^i, since payments between coalitions are not allowed. But all remaining owners can influence this choice. Owners who are linked this way in a dominance ranking between two structures M^i and M^j belong to the same *decisive group of owners with respect to market structures M^i and M^j*, denoted by $\mathcal{D}_g^{ij}$. The formal definition of a decisive group may appear somewhat opaque.[20] However, the concept itself is straightforward and, in "practice", it is very easy to find the decisive groups. For instance, in a dominance ranking of $M^D = \{12, 3\}$ and $M^T = \{1, 2, 3\}$, owner 3 belongs to identical firms in both structures and hence, is not decisive. The only decisive group with respect to these two structures is thus $D_1^{DT} = \{1, 2\}$. Or, in a dominance ranking of $M^D = \{12, 3\}$ and $M^M = \{123\}$, owners 1, 2 and 3 belong to different firms in the two structures. All three owners belong to a decisive group. The decisive groups are thus $\mathcal{D}_1^{DM} = \{1, 2, 3\}$.

M^j dominates M^i via a decisive group if and only if the combined profit of the decisive group is larger in M^j than in M^i. But, with more than one decisive group, these groups may dominate in opposite directions. It is therefore required that for M^j to *dominate* M^i, written M^j *dom* M^i, domination holds for *each* decisive group with respect to M^i and M^j.

The definition of decisive groups and the *dom* relation describes how to rank any pair of ownership structures. It remains to specify how these rankings should be employed in order to predict the outcome of the merger formation. To this end, define those structures that are *undominated*, i.e., that are at the core, as *Equilibrium Ownership Structures* (EOS).

To the best of our knowledge, all papers on mergers and cartels, i.e. "coordinated effects" theories, have treated the merger decision as exogenous, not determining the equilibrium merger. The focus of this section will be to identify the equilibrium merger under two different merger policies. The first is a *laissez-faire* policy under which all mergers to duopoly are allowed, but

[20] See Horn and Persson (2001a).

a merger to monopoly is forbidden. The second is a merger policy blocking any merger leading to a symmetric industry structure. We shall refer to the latter as an "anti-symmetric" merger policy.

Initially, we have the following Lemma (from Horn and Persson, 2001a):

Lemma 1 *Under the laissez-faire policy, the equilibrium merger gives rise to the highest aggregate duopoly profit.*

Proof. This follows from Proposition 2 in Horn and Persson (2001a) and from the fact that, in our model, the profit flows both under collusion and non-collusion regimes are time invariant. ■

Since we have assumed $c_1 = c$ and $c_2 = c_3 = 0$, the marginal costs associated with the possible merged entities are $c_{12} = c_{13} = c_{23} = 0$. So, two different market structures can result from our merger formation game: (i) a symmetric market structure M^A, resulting from a merger between firms 1 and 2 (or between firms 1 and 3). In this case, after the merger, both the merged entity and the outsider firm have zero variable costs; and (ii) an asymmetric market structure M^B resulting from a merger between firms 2 and 3. In this scenario, the merged entity faces zero variable costs, but the outsider firm 1 will face a variable cost $c > 0$. A merger leading to a symmetric industry structure M^A will occur in equilibrium, if the following condition holds:

$$\Pi^{Ah} = \pi_m^{Ah} + \pi_n^{Ah} > \pi_m^{Bk} + \pi_n^{Bk} = \Pi^{Bk}, \tag{5}$$

where $h, k = \{*, C\}$.

Our main finding in this context is that there exist fixed costs of collusion such that the equilibrium of the merger formation game is an efficient, non-collusive, symmetric duopoly under the *laissez-faire* policy, while the relevant alternative, if this merger is blocked, is an inefficient, collusive, asymmetric duopoly.

Applying condition (5) to the DPB model, we can derive the following result:

Proposition 3 *Let $c < c^*$. Under Assumptions 1-3 and 4a, we have that (i) at a fixed indivisible cost so low that collusion can be sustained in the symmetric case $(f < f')$, there will be a merger to a symmetric market structure M^A, (ii) at a fixed indivisible cost so high that collusion cannot be sustained in the symmetric case $(f > f')$, there exist parameter values in the DPB model where we will have mergers to an asymmetric market structure.*

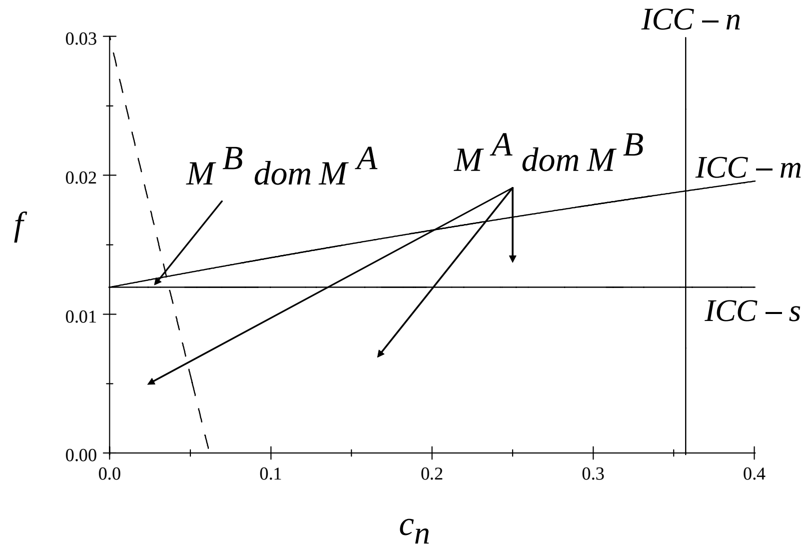

Figure 3: Equilibrium Market Structures

Proof. See Appendix D. ■

Figure 3 illustrates this result by indicating the equilibrium market structures for the different regions of parameter values.

As illustrated by Figure 3, an increase in the indivisible cost of collusion f may imply that firms will have an incentive to opt for a merger which creates an asymmetric industry structure M^B, which is conducive to a collusive equilibrium, i.e., an industry structure where one firm (the merged entity) will decide to cover the cost associated with being the cartel leader.

It should be noted, however, that the parameter area where M^B dominates M^A is rather small in Figure 3. The reason is that it is assumed that there are no synergies in a merger between the two efficient firms. Allowing for such synergies would imply that M^B would more likely be the equilibrium outcome of the game.

Let us now explicitly study the effects of an anti-symmetry merger policy in this context. Assuming that the regulator blocks mergers to symmetry but permits mergers to asymmetry, we have the following result:

Proposition 4 *A merger policy blocking mergers to a symmetric market* *structure can induce a merger without cost synergies (i.e. between firm 2 and firm 3), yielding a higher average production cost and a lower aggregated producer and consumer surplus.*

Proof. See Appendix E. ■

This result can be illustrated with the help of Figure 3. In what follows, let us focus on the region of parameter values for which $ICC-m$ and $ICC-n$ hold, but $ICC-s$ does not. Then, consider the merger condition (5) which in this case becomes:

$$\Pi^{A*} = \pi_m^{A*} = \pi_n^{A*} > \pi_m^{BC} + \pi_n^{BC} = \Pi^{BC}. \tag{6}$$

The downward sloping dashed line represents merger condition (6) when it is binding. As illustrated by Figure 3, this dashed line divides the region under consideration into two different subregions. In the right-hand subregion, M^A dominates M^B, whereas the opposite holds in the left-hand subregion.

At this point, it is important to note that in the whole region under analysis, firms will not be able to collude in case a merger results in a perfectly symmetric market structure. Therefore, the reason why the symmetric market structure M^A dominates the asymmetric market structure M^B in the right-hand subregion of the region under analysis is not the fact that a merger to symmetry results in collusion amongst the remaining firms in the market. Instead, what drives this result is that this merger will give rise to very significant savings of production costs.

So, by adopting an anti-symmetry merger policy, antitrust authorities *force* firms to opt for the merger leading to the asymmetric market structure, M^B. This alternative merger will, in the region under analysis, create the most favorable conditions for collusion to arise, since the asymmetries between the two remaining firms are moderate after the merger (see Proposition 1 and Figure 1). In addition, for some parameter values, the gains from successful collusion which are obtained in this asymmetric industry structure are so high that they will more than compensate for the fact that one of the colluding firms has high production costs. Consequently, by forbidding a merger leading to a symmetric industry structure, competition authorities may end up with a merger that does not only result in less efficient production, but also facilitates collusion.

3 Endogenizing the cost of cartelization

We here provide an example of an endogenous indivisible cost of creating and protecting a cartel. As described in the introduction, in 1987 Brown Boveri Company (later ABB) embarked on a strategic program of acquiring district heating pipe producers across Europe. However, this program was considered to be unfairly costly by ABB as indicated by the following quote from §28 of the EC Decision: "ABB for its part considers that it was unfairly having to bear all the cost of industry reorganization while other producers obtained a free ride." Moreover, in reaction to Powerpipe's aggressive behavior and entry into new geographical markets, ABB decided to use several predatory strategies to protect the cartel.

To capture these aspects of creating and maintaining the cartel, consider the following modified model set-up, where we keep the repeated oligopoly game we had before, but change the first-stage interaction in the following way. Now, firm 3 is outside the market and contemplates entering it, incurring an exogenous entry cost $\mathcal{E} \geqslant 0$. The cartel might prevent this entry by buying out the potential entrant. To this end, we assume that firm 2 makes a take-it-or-leave-it offer $\mathcal{A}$ to firm 3. In order to keep the analysis consistent with the analysis in the previous sections we transform the acquisition price $\mathcal{A}$ to the per-period acquisition price A equivalent, and the entry cost $\mathcal{E}$ to the per-period entry cost E equivalent. It should be noted, however, that the qualitative results of the present section would also hold in case we modelled the acquisition price and entry cost as lump sum paid upfront.

There are two scenarios to consider, one with and one without an acquisition:

Case 1: Entry. In this case, firm 3 enters the market facing a variable cost c_3. It is assumed that if entry occurs, collusion is not sustainable and firms compete à la Bertrand in each period, generating profits $\pi_1^B(c_1, c_2, c_3)$, $\pi_2^B(c_1, c_2, c_3)$, and $\pi_3^B(c_1, c_2, c_3)$, respectively. This assumption of one-shot Bertrand competition could be supported by the fact that collusion is not sustainable with three firms in the market or by firm 3 deciding to denounce the existence of the collusive agreement to the antitrust authorities about the illegal behavior upon entering the market.[21]

[21] See Friedman and Thisse (1994, p. 272).

Case 2: Buyout. To focus on the buyout as an indivisible collusion cost, we assume that a buyout would not be profitable if collusion did not occur post buyout. Then, we can use the above set-up to determine whether there will be collusion, taking the indivisible buyout cost into account. It immediately follows that if a buyout takes place in equilibrium, firm 2 will make an offer equal to firm 3's reservation price, i.e. its profit if it enters. The ICC for firm 2 is then given by:

$$\sum_{t=0}^{\infty}\left[\pi_2^C\left(p_2^C,p_1^C,c_1,c_2\right)-A\right]\cdot\delta^t>\pi_2\left(p_2^*\left(p_1^C\right),p_1^C,c_1,c_2\right)+\sum_{t=1}^{\infty}\pi_2\left(p_2^B,p_1^B,c_1,c_2\right)\delta^t, \tag{7}$$

where the indivisible acquisition cost $A=\pi_3^B\left(c_1,c_2,c_3\right)-E$ is the reservation price of firm 3. The ICC for firm 1 is given by

$$\sum_{t=0}^{\infty}\pi_1^C\left(p_1^C,p_2^C,c_1,c_2\right)\delta^t>\pi_1\left(p_1^*\left(p_2^C\right),p_2^C,c_1,c_2\right)+\sum_{t=1}^{\infty}\pi_1\left(p_1^B,p_2^B,c_1,c_2\right)\delta^t. \tag{8}$$

To simplify the presentation, we assume the buyout price A to be independent of the level of asymmetry, i.e. $A=\pi_3^B\left(c_1,c_2,\overline{c_3}\right)-E=\overline{A}$. Consequently, it is assumed that if c_1 decreases, c_2 will increase in such a way that the acquisition price will not change. Then, using assumptions A1, A2, A3, and A4a, it directly follows that we can make use of the graphical solution in Figure 1 to describe the equilibrium, where we have c_1 (the marginal cost of the incumbent not participating in the merger) on the horizontal axis and the vertical axis now represents A (instead of f).

What will then happen if we relax the assumption that the acquisition price is independent of the cost asymmetry? If the buyout price (reservation price) decreases in asymmetries, collusion becomes relatively more likely under asymmetry, whereas the opposite is true if the buyout price increases in asymmetries.

We then make use of the DPB model to show the existence of an equilibrium where the buyout of a collusion breaking potential entrant will be undertaken, if and only if the market structure is medium asymmetric. Thus, we can show that:

Proposition 5 *There exist parameter values in the DPB model under the joint profit-maximizing rule such that firm 2 buys out firm 3 if and only* *if collusion occurs post-buyout, which is the case if and only if the market structure is moderately asymmetric.*

Proof. See Appendix F. ■

Moreover, it immediately follows that if the entry cost E increases the buy-out price, A decreases. This, in turn, implies that a more symmetric market structure could support collusion when the exogenous entry barriers are high. Consequently, we can state the following result:

Corollary 1 *The lower is the exogenous entry barrier, the more asymmetric must the market structure be to sustain collusion, since entry-deterring takeovers to protect the cartel then become more costly.*

Consequently, an empirical prediction of the model is that we should observe more asymmetric cartels in markets with lower exogenous entry barriers.

4 Conclusion

In the existing literature, mergers leading to a symmetric size distribution (cost structure) of firms have been shown to increase the risk of collusion, since the asymmetry between firms creates incentives to deviate both in the collusive phase and in the punishment phase. Allowing for indivisible costs of collusion, which one firm must bear (a ring leader), we show that forbidding mergers leading to symmetric market structures can induce mergers leading to asymmetric market structures with higher production costs and a higher risk of collusion. In particular, we show that if the rule determining the collusive outcome has the property of the large (efficient) firm benefitting sufficiently more from collusion when industry asymmetries increase, collusion can become more likely when firms are asymmetric.

These results highlight the importance of studying the environment for post merger collusion in detail, taking into account the role played by a potential ring-leader in the collusion process.

The key to our result is the chosen rule for determining the collusive outcome. If the cartel behavior rule has the property of the gains of the large (efficient) firm from collusion increasing with industry asymmetries, our main results are valid. Basically, what is important is that the "advantages" of the large (efficient) firm in the non-cooperative interaction (e.g. its larger market share, lower production costs, larger capital stock, or higher quality products) are used to give leverage in capturing more of the surplus created by collusion. This will be the case for some particular rules of how to determine the cartel outcome. As shown above, a rule with this characteristic is joint profit maximization. But this rule has some problematic features, as discussed in Harrington (2004). In particular, it could allocate the gains from collusion very unevenly.

Notice, however, that the constant market shares rule, which is one of the most frequently used allocation rules, also has some odd features in our setting: the small (inefficient) firm gains more from collusion than the large (efficient) firm. The reason is that under the constant market share rule, the large (efficient) firm is forced to reduce output much more than the small (inefficient) firm, which implies that the "cost" due to the output reduction to a larger extent falls on this large (efficient) firm.[22] This rule is evidently used in practice, but this property suggests that other rules should be used where the large (efficient) firm gains most from collusion. For example, we show that the large (efficient) firm gains most from collusion under an equal price increase rule. However, more research is needed to better understand which rules are used in what context and what are their implications for coordinated effects of mergers.

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A The DPB model

Here, we will describe the DPB model used to derive specific results.

Consider an infinitely repeated game with two firms, denoted by subscripts $i = 1, 2$. Each firm produces a single variety of a good X and the quantity of variety i is denoted q_i. The fixed costs of production are taken to be zero and firm i's constant marginal cost is given by c_i. Let $c_1 = 0$ and $c_2 = c > 0$.

Following Singh and Vives (1984), we assume that a representative consumer maximizes the following utility function:

$$U(q_1, q_2) = a_1 q_1 + a_2 q_2 - \frac{1}{2}\left(b_1 q_1^2 + b_2 q_2^2 + 2\theta q_1 q_2\right) + y, \tag{9}$$

where y is a numeraire 'outside' good. This utility function gives rise to a linear demand structure, where direct demand can be written as:

$$q_1(p_1, p_2) = \alpha_1 - \beta_1 p_1 + \gamma p_2 \tag{10}$$

$$q_2(p_1, p_2) = \alpha_2 - \beta_2 p_2 + \gamma p_1, \tag{11}$$

where $d \equiv \left(b_1 b_2 - \theta^2\right)$, $\alpha_i \equiv (a_i b_j - a_j \theta)/d$, $\beta_i \equiv b_j/d$ for $i \neq j$, $i = 1, 2$, and $\gamma \equiv \theta/d$.

Firms compete in prices. Every period of time can be divided into the following stages: firms first set prices, consumers then determine the demand for the two varieties of the good and, finally, markets clear.

The profit of firm i is $\Pi_i = \sum_{t=0}^{\infty} \delta^t \cdot \pi_i^t(p_1^t, p_2^t)$, where p_i^t is the price charged by firm i in period t and firm i's individual profit in period t is

$$\pi_i\left(p_1^t, p_2^t\right) = q_i\left(p_1^t, p_2^t\right) \cdot \left[p_i^t - c_i\right]. \tag{12}$$

A.1 Non-cooperative behavior and joint profit maximization

Consider a single period game. If the firms play noncooperatively, each firm solves the following optimization problem

$$\max_{p_i} \quad q_i(p_1, p_2) \cdot (p_i - c_i). \tag{13}$$

From the first-order conditions (FOCs) of the previous maximization problem, it can be concluded that the (positively sloped) reaction functions of firms 1 and 2 are, respectively, given by:

$$p_1^*(p_2) = \frac{\alpha_1 + \gamma p_2}{2\beta_1}, \tag{14}$$

$$p_2^*(p_1) = \frac{\alpha_2 + \beta_2 c + \gamma p_1}{2\beta_2}. \tag{15}$$

Now, some algebra shows that in the unique Bertrand-Nash equilibrium of the one-shot game, firms' prices and individual profits are:

$$p_1^B = \frac{2\alpha_1\beta_2 + \alpha_2\gamma + \beta_2\gamma c}{4\beta_1\beta_2 - \gamma^2}, \tag{16}$$

$$p_2^B = \frac{2\alpha_2\beta_1 + \alpha_1\gamma + 2\beta_1\beta_2 c}{4\beta_1\beta_2 - \gamma^2}, \tag{17}$$

$$\pi_1\left(p_1^B, p_2^B\right) = \beta_1 (p_1^B)^2, \tag{18}$$

$$\pi_2\left(p_1^B, p_2^B\right) = \beta_2 \left(\frac{2\alpha_2\beta_1 + \alpha_1\gamma + c\left(\gamma^2 - 2\beta_1\beta_2\right)}{4\beta_1\beta_2 - \gamma^2}\right)^2. \tag{19}$$

If firms instead decide to maximize their joint profit in the one-shot game, their equilibrium prices result from the following optimization problem:

$$\max_{p_1, p_2} \quad \sum_{i=1}^{2} q_i\left(p_1, p_2\right) \cdot \left(p_i - c_i\right). \tag{20}$$

From the FOCs of the previous maximization problem, and after some rearranging, it is concluded that the cooperative prices of firms 1 and 2 are, respectively, given by:

$$p_1^C = \frac{\alpha_2\gamma + \alpha_1\beta_2}{2\left(\beta_1\beta_2 - \gamma^2\right)}, \tag{21}$$

$$p_2^C = \frac{\alpha_2\beta_1 + \alpha_1\gamma + c\left(\beta_1\beta_2 - \gamma^2\right)}{2\left(\beta_1\beta_2 - \gamma^2\right)}. \tag{22}$$

In addition, firms' collusive equilibrium profits are:

$$\pi_1\left(p_1^C, p_2^C\right) = \frac{\left(\alpha_1 + c\gamma\right)\left(\alpha_2\gamma + \alpha_1\beta_2\right)}{4\left(\beta_1\beta_2 - \gamma^2\right)}, \tag{23}$$

$$\pi_2\left(p_1^C, p_2^C\right) = \frac{\left(\alpha_2 - c\beta_2\right)\left(\alpha_2\beta_1 + \alpha_1\gamma + c\left(\gamma^2 - \beta_1\beta_2\right)\right)}{4\left(\beta_1\beta_2 - \gamma^2\right)}. \tag{24}$$

A.2 Deviation profits

If a given firm is considering to deviate in period t, when firms are supposed to set prices (21) and (22) then, making use of firms' reaction functions (14) and (15), it may be concluded that each firm's optimal deviation price is given by:

$$p_1^*\left(p_2^C\right) = \frac{\alpha_1\left(2\beta_1\beta_2 - \gamma^2\right) + \gamma\alpha_2\beta_1 - c\gamma\left(\gamma^2 - \beta_1\beta_2\right)}{4\beta_1\left(\beta_1\beta_2 - \gamma^2\right)}, \tag{25}$$

and

$$p_2^*\left(p_1^C\right) = \frac{\alpha_2\left(2\beta_1\beta_2 - \gamma^2\right) + \gamma\alpha_1\beta_2 - 2c\beta_2\left(\gamma^2 - \beta_1\beta_2\right)}{4\beta_2\left(\beta_1\beta_2 - \gamma^2\right)}. \tag{26}$$

Hence, the corresponding deviation profits for firms 1 and 2 are, respectively, given by:

$$\pi_1\left(p_1^*\left(p_2^C\right), p_2^C\right) = \beta_1\left(p_1^*\left(p_2^C\right)\right)^2, \tag{27}$$

$$\pi_2\left(p_1^C, p_2^*\left(p_1^C\right)\right) = \frac{\left(\alpha_2\left(2\beta_1\beta_2 - \gamma^2\right) + \gamma\alpha_1\beta_2 + 2\beta_2 c\left(\gamma^2 - \beta_1\beta_2\right)\right)^2}{16\beta_2\left(\gamma^2 - \beta_1\beta_2\right)^2}. \tag{28}$$

B Generating Figures 1 and proving Proposition 1

In what follows, let $\alpha_1 = \alpha_2 = \beta_1 = \beta_2 = 1$ and $\gamma = 1/3$.

B.1 Deriving Figure 1

B.1.1 Curve ICC-s

Making use of eqs. (4), (18), (23), (27), some algebra shows that:

$$f' = \overline{f}\left(0, \delta\right) = \frac{3}{8} - \left(1 - \delta\right)\frac{25}{64} - \delta\frac{9}{25}. \tag{29}$$

For a given (and sufficiently high) value of the discount factor δ, the previous equation is represented by the horizontal line ICC-s in Figure 1.

B.1.2 Curve ICC-n

Making use of eqs. (3), (19), (24) and (28), and after some rearranging, it may be concluded that condition (3) becomes:

$$\frac{(1-c_n)(3-2c_n)}{8}\frac{1}{1-\delta} > \frac{(5-4c_n)^2}{64} + \frac{(21-17c_n)^2}{1225}\frac{\delta}{1-\delta}. \tag{30}$$

Now, for a given value of δ, the value of c_n for which the previous condition binds is represented by the vertical line ICC-n in Figure 1.

B.1.3 Curve ICC-m

Combining the results in eqs. (4), (18), (23), (27), it may be concluded that:

$$\overline{f}(c_n,\delta) = \frac{1}{8}(c_n+3) - (1-\delta)\frac{(2c_n+15)^2}{576} - \delta\frac{9(c_n+7)^2}{1225}. \tag{31}$$

For a given δ, the previous condition is represented by the ICC-m curve in Figure 1.

So, this section proves that there exist parameter values in the DPB model such that Figure 1 is valid, as claimed in Proposition 1.

C Alternative cartel behavior rules

In Appendices A and B, joint profit maximization was used as a criterion for selecting the collusive outcome. This section studies the properties of two other alternative cartel behavior rules which have been used in practice: the equal price increase rule and the constant market shares rule.

As before, we focus the attention on a specific parametrization of the DPB model where $\alpha_1 = \alpha_2 = \beta_1 = \beta_2 = 1$ and $\gamma = 1/3$. This being the case, from eqs. (16), (18) and (19), it may be concluded that the Bertrand-Nash equilibrium profits are given by:

$$\pi_1\left(p_1^B, p_2^B, c\right) = \frac{9(7+c)^2}{1225}, \tag{32}$$

$$\pi_2\left(p_1^B, p_2^B, c\right) = \frac{(21-17c)^2}{1225}. \tag{33}$$

C.1 The equal price increase rule

Suppose that along the collusive path, each firm reduces its output by the same amount $\Delta > 0$ (leading to an equal price increase). Notice that firm i's optimal value of Δ results from the following maximization problem:[23]

$$\max_{\Delta} \left(\frac{3}{2} - \frac{9}{8} \left(q_i^B - \Delta \right) - \frac{3}{8} \left(q_j^B - \Delta \right) - c_i \right) \left(q_i^B - \Delta \right), \tag{34}$$

where q_i^B denotes firm i's quantity in the Bertrand-Nash equilibrium, $i, j = 1, 2, i \neq j$. It can easily be checked that the optimal values of Δ for firms 1 and 2 are, respectively, given by:

$$\Delta_1^* = \frac{1}{10} + \frac{1}{70} c, \tag{35}$$

$$\Delta_2^* = \frac{1}{10} - \frac{17}{210} c. \tag{36}$$

So, the two firms in the cartel will have to bargain over the value of $\Delta \in [\Delta_2^*, \Delta_1^*]$. Assume that the chosen level of Δ will be $(\Delta_2^* + \Delta_1^*)/2$. The corresponding cooperative prices and profits are then given by:

$$\widehat{p}_1^C = \frac{3}{4} + \frac{1}{28} c, \tag{37}$$

$$\widehat{p}_2^C = \frac{3}{4} + \frac{13}{28} c, \tag{38}$$

$$\widehat{\pi}_1^C = \frac{(21 + c)(21 + 5c)}{1176}, \tag{39}$$

$$\widehat{\pi}_2^C = \frac{(7 - 5c)(21 - 19c)}{392}. \tag{40}$$

Now, making use of eqs. (14), (15), (37) and (38), it is shown that the optimal deviation prices for firms 1 and 2 are, respectively, given by:

$$p_1^* \left(\widehat{p}_2^C \right) = \frac{5}{8} + \frac{13}{168} c, \tag{41}$$

[23] Making use of eqs. (10)-(11), it is straightforward to conclude that, for the specific parameter values we have chosen, firm i's inverse demand function is given by $p_i = 3/2 - 9/8 q_i - 3/8 q_j$.

$$p_2^*\left(\widehat{p}_1^C\right) = \frac{5}{8} + \frac{85}{168}c. \tag{42}$$

The corresponding optimal deviation profits are:

$$\widehat{\pi}_1^D = \frac{(105 + 13c)^2}{28\,224}, \tag{43}$$

$$\widehat{\pi}_2^D = \frac{(105 - 83c)^2}{28\,224}. \tag{44}$$

So, combining eqs. (4), (32), (39) and (43), it may be concluded that

$$\overline{f}_\Delta(c_n, \delta) = \frac{(21 + c_n)(21 + 5c_n)}{1176} - (1 - \delta)\frac{(105 + 13c_n)^2}{28\,224} - \delta\frac{9(7 + c_n)^2}{1225}. \tag{45}$$

Now, it can easily be checked that, for a given value of δ (say $\delta = 0.9$), $\overline{f}_\Delta(c_n, \delta)$ increases in c_n in the relevant region of parameter values. So, the previous condition can be represented by such an upward sloping ICC-m curve as that presented in Figure 1.

C.2 The constant market shares rule

Suppose that along the collusive path, firm i's output is $q_i^C = \alpha q_i^B$, where q_i^B denotes firm i's quantity in the Bertrand-Nash equilibrium, $i, j = 1, 2, i \neq j$, and $\alpha \in (0, 1)$. When this is the case, each firm's market share along the collusive path coincides with its market share at the Bertrand Nash equilibrium. The problem, however, is to identify the value of α chosen by the cartel.

Note that firm i's optimal value of α results from the following maximization problem:

$$\max_\alpha \left(\frac{3}{2} - \frac{9}{8}\alpha q_i^B - \frac{3}{8}\alpha q_j^B - c_i\right)\alpha q_i^B. \tag{46}$$

It can easily be checked that the optimal values of α for firms 1 and 2 are, respectively, given by:

$$\alpha_1^* = \frac{35}{2(21 - 2c)}, \tag{47}$$

$$\alpha_2^* = \frac{35}{18}\frac{3 - 2c}{7 - 4c}. \tag{48}$$

So, the two firms in the cartel will have to bargain over the value of $\alpha \in [\alpha_2^*, \alpha_1^*]$. Let the chosen level of α be $\widetilde{\alpha}_1$.[24] The corresponding cooperative prices and profits are then given by:

$$\widetilde{p}_1^C = \frac{3}{4}, \tag{49}$$

$$\widetilde{p}_2^C = \frac{3}{4}\frac{21+8c}{21-2c}, \tag{50}$$

$$\widetilde{\pi}_1^C = \frac{9}{8}\frac{7+c}{21-2c}, \tag{51}$$

$$\widetilde{\pi}_2^C = \frac{1}{8}\frac{(21-17c)\left(8c^2-60c+63\right)}{(21-2c)^2}. \tag{52}$$

Now, making use of eqs. (14), (15), (49) and (50), it is shown that the optimal deviation prices for firms 1 and 2 are, respectively, given by:

$$p_1^*\left(\widetilde{p}_2^C\right) = \frac{105}{8(21-2c)}, \tag{53}$$

$$p_2^*(p_1) = \frac{5}{8} + \frac{1}{2}c. \tag{54}$$

The corresponding optimal deviation profits are:

$$\widetilde{\pi}_1^D = \frac{11\,025}{64(21-2c)^2}, \tag{55}$$

$$\widetilde{\pi}_2^D = \frac{(5-4c)^2}{64}. \tag{56}$$

C.2.1 Deriving Figure 2

Curve ICC-s Making use of eqs. (4), (32), (51) and (55), some algebra shows that:

$$f' = \overline{f}(0,\delta) = \frac{9}{8}\frac{7}{21} - (1-\delta)\frac{11\,025}{64(21)^2} - \delta\frac{9(7)^2}{1225}. \tag{57}$$

For a given (and sufficiently high) value of δ, the previous equation is represented by the horizontal line ICC-s in Figure 2.

[24] Since we have assumed the most efficient firm to be the one which must cover indivisible per-period coordination fixed costs, it may be natural to assume that it has all the bargaining power in the choice of α.

Curve ICC-n Making use of eqs. (33), (52) and (56), it may be concluded that condition (3) can be rewritten as:

$$\frac{1}{1-\delta}\frac{1}{8}\frac{(21-17c_n)(8c_n^2-60c_n+63)}{(21-2c_n)^2} > \frac{(5-4c_n)^2}{64}+\frac{(21-17c_n)^2}{1225}\frac{\delta}{1-\delta}. \tag{58}$$

For a given value of δ, the value of c_n for which the previous constraint is binding is represented by the vertical line ICC-n in Figure 2.

Curve ICC-m Combining the results in eqs. (4), (32), (51) and (55), it may be concluded that:

$$\overline{f}(c_n,\delta) = \frac{9}{8}\frac{7+c_n}{21-2c_n} - (1-\delta)\frac{11\,025}{64(21-2c_n)^2} - \delta\frac{9(7+c_n)^2}{1225}. \tag{59}$$

It can easily be checked that for a given sufficiently high value of the discount factor δ, $\overline{f}(c_n,\delta)$ decreases in c_n. So, the previous condition is represented by the downward sloping curve ICC-m in Figure 2.

D Proof of Proposition 3

Take the specific parametrization of the DPB model used above, where $\alpha_1 = \alpha_2 = \beta_1 = \beta_2 = 1$ and $\gamma = 1/3$.

If the two firms, whose constant marginal costs are c_1 and c_2, play non-cooperatively, then it is easily shown that their Bertrand-Nash equilibrium profits are given by:

$$\pi_1^B(c_1,c_2) = \frac{1}{1225}(21-17c_1+3c_2)^2, \tag{60}$$

$$\pi_2^B(c_1,c_2) = \frac{1}{1225}(21+3c_1-17c_2)^2. \tag{61}$$

If firms instead decide to maximize their joint profit in the one-shot game, their equilibrium profits will be as follows:[25]

$$\pi_1^C(c_1,c_2) = \frac{1}{24}(3c_1-c_2-3)(2c_1-3), \tag{62}$$

[25] If $c_1 = 0$ and $c_2 = c$, eqs. (60) and (60) boil down to eqs. (32) and (33), respectively.

$$\pi_2^C(c_1,c_2)=\frac{1}{24}(3c_2-c_1-3)(2c_2-3). \quad (63)$$

Some algebra also shows that firms' deviation profits are equal to:

$$\pi_1^D(c_1,c_2)=\frac{1}{576}(12c_1-2c_2-15)^2, \quad (64)$$

$$\pi_2^D(c_1,c_2)=\frac{1}{576}(12c_2-2c_1-15)^2. \quad (65)$$

Now two different cases should be considered, which we discuss in turn.

1. Consider first the case where $f<f'$ so that collusion can be sustained if there is a merger inducing a symmetric market structure, M^A. Notice that since $c_n<c^*$, we also have that in case there is a merger (between firms 2 and 3) leading to an asymmetric market structure M^B, the remaining firms in the industry will be able to collude (both the ICC-m and the ICC-n hold after the merger, as illustrated by Figure 1). So, condition (5) boils down to:

$$\Pi^{AC}=\pi_m^{AC}+\pi_n^{AC}>\pi_m^{BC}+\pi_n^{BC}=\Pi^{BC}. \quad (66)$$

Now, making use of eqs. (62) and (63), simple algebra shows that:

$$\pi_m^{AC}=\left(\frac{3}{8}-f\right)\frac{1}{1-\delta}, \quad (67)$$

$$\pi_n^{AC}=\frac{3}{8}\frac{1}{1-\delta}, \quad (68)$$

$$\Pi^{AC}=\left(\frac{3}{4}-f\right)\frac{1}{1-\delta}, \quad (69)$$

$$\pi_m^{BC}=\left(\frac{1}{8}(c_n+3)-f\right)\frac{1}{1-\delta}, \quad (70)$$

$$\pi_n^{BC}=\frac{1}{8}(1-c_n)(3-2c_n)\frac{1}{1-\delta}, \quad (71)$$

$$\Pi^{BC}=\frac{1}{4}\frac{c_n^2-2c_n+3-4f}{1-\delta}. \quad (72)$$

Hence, some algebra shows that condition (66) holds if

$$\frac{1}{4}\frac{c_n(2-c_n)}{1-\delta}>0, \quad (73)$$

which turns out to always be true.

2. Consider now the case in which $f > f'$. More specifically, consider the region of Figure 1 in which ICC-m and ICC-n hold, but ICC-s does not. In this region, firms will not collude in the symmetric market structure M^A. Hence, making use of eqs. (60)-(61), it can easily be concluded that in this symmetric market structure, the present discounted value of individual firms' profits and the industry profit is, respectively, given by:

$$\pi_m^{A*} = \pi_n^{A*} = \frac{9}{25}\frac{1}{1-\delta}, \tag{74}$$

$$\Pi^{A*} = \frac{18}{25}\frac{1}{1-\delta}. \tag{75}$$

On the other hand, and restricting the attention to the same region of parameter values, it is shown that firms will be able to collude in the asymmetric market structure, M^B. Therefore, and as already shown, in this asymmetric market structure M^B, the present discounted value of individual firms' profits and the industry profit is, respectively, given by eqs. (70), (71) and (72).

So, since in this region, firms will not collude in the symmetric market structure M^A but will be able to collude in the asymmetric market structure M^B (see Figure 1), condition (5) boils down to:

$$\Pi^{A*} = \pi_m^{A*} = \pi_n^{A*} > \pi_m^{BC} + \pi_n^{BC} = \Pi^{BC}. \tag{76}$$

Now, making use of eqs. (75) and (72), it may be concluded that the previous merger condition will be satisfied if fixed indivisible costs associated with collusion are sufficiently high, i.e.:

$$f > \frac{c_n^2 - 2c_n + 3}{4} - \frac{18}{25}. \tag{77}$$

The previous condition, when it is binding, is represented by the downward sloping dashed curve in Figure 3.

As a final remark, **note** that in Figure 3, we assume that $\delta = 0.9$. This being the case and making use of eqs. (29) - (31), it is straightforward to show that the equations representing the ICC-s, the ICC-n and the ICC-m curves are, respectively, given by:

$$f' = \overline{f}\,(0, 0.9) = 0.011938, \tag{78}$$

$$c^* = 0.35742, \tag{79}$$

$$\overline{f}(c_n, 0.9) = \frac{1}{8}(c_n + 3) - 0.1\frac{(2c_n + 15)^2}{576} - 8.1\frac{(c_n + 7)^2}{1225}. \tag{80}$$

E Proof of Proposition 4

Let us restrict the attention to the region of parameter values in which the ICC-m and the ICC-n hold, but the ICC-s does not. As shown in Proposition 3 (and illustrated in Figure 3), there exists a subregion of parameter values where M^A dominates M^B. This subregion is the one to the right of the dashed line in Figure 3. So, in this area, if the antitrust authority forbids a merger creating a symmetric market structure M^A, firms will be induced to choose a merger creating an asymmetric industry structure, M^B.

By creating an asymmetric industry structure, this merger between firms 2 and 3 yields an higher average production cost and a lower aggregated producer surplus than that leading to a symmetric market structure M^A (recall that, as shown in Proposition 3, M^A dominates M^B under a laissez-faire policy). To complete the proof, however, we also need to show that a merger leading to M^B gives rise to a lower consumer surplus than a merger leading to M^A, i.e., we need to check whether the prices charged by the merged entity and the non-merged firm are higher in market structure M^B than in market structure M^A. Regarding the merged entity (firm m), making use of eqs. (16) and (21), it is easy to check that it will charge higher prices in case the ex-post merger market structure is M^B, since:

$$p_m^{A*} = \frac{3}{5} < p_m^{BC} = \frac{3}{4}. \tag{81}$$

As for the non merged entity (firm n), making use of eqs. (17) and (22), it is simple to check that it will also set a higher price in market structure M^B than in market structure M^A, since:

$$p_n^{A*} = \frac{3}{5} < p_n^{BC} = \frac{1}{4}(2c_n + 3), \tag{82}$$

which is true for any $c_n > 0$. Hence, a merger leading to an asymmetric market structure M^B will, in the region under consideration, give rise to a lower consumer surplus than a merger leading to a completely symmetric industry structure, M^A. This completes the proof of Proposition 4.

F Proof of Proposition 5

Continue to consider the specific parametrization of the DPB model used above, where $\alpha_1 = \alpha_2 = \beta_1 = \beta_2 = 1$ and $\gamma = 1/3$.

Now, making use of eq. (7), it may be concluded that the maximum acquisition cost $\widetilde{A}$ that firm 2 would be willing to pay is the one for which the ICC (7) is binding, i.e.,

$$\widetilde{A} = \pi_2^C \left(p_2^C, p_1^C, c_1, c_2\right) - (1-\delta)\pi_2 \left(p_2^* \left(p_1^C\right), p_1^C, c_1, c_2\right) - \delta\pi_2 \left(p_2^B, p_1^B, c_1, c_2\right), \tag{83}$$

which, making use of eqs. (60)-(65) can, for the specific parametrization of the DPB model we have been using throughout the paper, be rewritten as:

$$\begin{aligned} \widetilde{A}(c_1, c_2, \delta) &= \left(\frac{1}{24}(3c_2 - c_1 - 3)(2c_2 - 3)\right) - (1-\delta)\left(\frac{1}{576}(12c_2 - 2c_1 - 15)^2\right) \\ &\quad -\delta\frac{1}{1225}(21 + 3c_1 - 17c_2)^2. \end{aligned} \tag{84}$$

Now, while the previous equation puts forward the threshold value for the acquisition price, the actual acquisition price is $A = \pi_3^B(c_1, c_2, \overline{c_3})$. For the specific parametrization of the DPB model we are using, it is straightforward to show that firm 3's individual (triopoly) profits in a Bertrand-Nash equilibrium are given by:

$$\pi_3^B(c_1, c_2, c_3) = \frac{(13c_3 - 3c_1 - 3c_2 - 21)^2}{784} - F_3 \equiv A(c_1, c_2, \overline{c_3}), \tag{85}$$

where $F_3 \geq 0$ denotes firm 3's fixed costs of production.

Consider now an example where $\delta = 0.9$, $c_2 = 0.1$, $\overline{c_3} = c_1$ and $F_3 = 0.4$. Figure 4 then presents the threshold acquisition price $\widetilde{A}(c_1, c_2 = 0.1, \delta = 0.9)$ (solid upward sloping curve) and the actual acquisition price $A(c_1, c_2 = 0.1, \overline{c_3} = c_1)$ (dashed downward sloping curve). So, firm 2 will decide to buy out firm 3 and collude after this buyout in the region where the dashed decreasing curve is below the solid upward sloping curve (so that the actual price paid to acquire firm 3 is lower than the maximum threshold price $\widetilde{A}$ identified above). In addition, Figure 4 also presents a vertical line which represents firm 1's ICC (eq. (8)), which making use of eqs. (60), (62) and (85) and for the specific parametrization of the model we are using in this example, implies that firm 1 will decide to collude if $c_1 \leq 0.43360$.

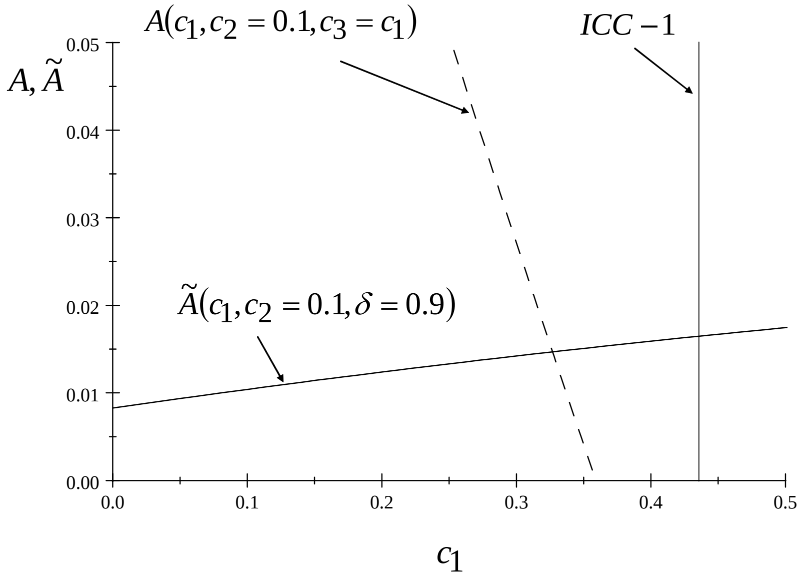

Figure 4: Equilibrium Pattern when Indivisible Costs are Endogenous

So, clearly, firm 2 will decide to buy out firm 3 and collusion between firms 1 and 2 will take place in the market structure induced by this **buyout,** if costs are medium asymmetric. This completes the proof of Proposition 5.