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Market Power and Incentives to Form Research Consortia

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Abstract. It is well known that instability is a limit to the formation of cartels, and that some synergies are required to give cartel members an advantage over outsiders. In this paper, we explore theoretically the linkage between cost-reduction alliances (like research joint ventures) and the formation of cartels. The former have negative external impacts on outsiders, while the latter have positive external effects on outside (independent) competitors. We find that when the decisions to join both are made simultaneously the cartel can be profitable and stable for a smaller number of members than previously found for cartel formation alone by Salant et al. (1983, Quarterly Journal of Economics **98**, 185–199). This result follows both for open membership and exclusive membership rules, and suggests a possible anticompetitive impact of research joint ventures.

Key words: cartel, group formation, RJV.

JEL Classifications: D21, D43.

I. Introduction

Starting in the early 1980s, concern with declining US industrial competitiveness in world markets – and envy of European and Japanese competitors for their (then) success in investment, R&D, and productivity gains – led to calls for the encouragement, if not outright subsidy, of research activities by US firms. In particular, joint research activities – research consortia – were seen as a possible solution. At the time, not much was made of the widely-held view (especially by industrial organization economists) that these foreign competitors also tended to have less competitive markets than those faced by most US firms.[1] It was acknowledged that cooperation by firms in research activities could potentially lead to cooperation/collusion at the output stage – or at least the perception of collusion from the standpoint of antitrust authorities – but the solution seen

[1] See for example, Competitiveness Policy Council (1992), Dertouzos et al. (1989), Melese and Michel (1990) and Romer (1993).

was more often to shield firms in research consortia from antitrust enforcement than to intervene actively to limit such collusion.[2]

Of course, there has been concern expressed about the anti-competitive implications of these cooperative research activities,[3] with most of the focus on the potential for explicit collusion – and alerting antitrust enforcers to this. However, Feinberg (1995) pointed out that the effects may be more subtle in the sense that a longer time horizon – either culturally determined (as might be appropriate in cross-country comparisons) or induced by R&D cooperation – might make tacitly collusive solutions to noncooperative games more likely.[4]

Snyder and Vonortas (2005) note that multi-project contact – not simply participation in research consortia – has been identified as a possible anticompetitive concern,[5] but they provide a model in which such bundling of research projects is welfare-enhancing. In this paper, we more formally investigate the linkages between potential market power and the incentives for the formation of research consortia, on the one hand, and the implications for the exploitation of market power by participants in these consortia, on the other.[6]

II. Some Empirical Context

Before developing a theoretical approach to examining the issues, we present some descriptive data suggestive of a link between research collaboration and output market power. After obtaining data on US manufacturing firms that registered a "research joint venture" (RJV) with the US Department of Justice and Federal Trade Commission under the National Cooperative Research Act of 1984 (through 2000) and their primary industry classification, we have collected industry data on the 50 four-digit SIC industries in which there were at least five firms registered over that period.[7]

A few results are interesting: (1) these "RJV-intensive" industries are slightly less concentrated on average (for 1992) than the all-manufacturing

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[2] For example, see Jorde and Teece (1990).

[3] Examples are Brodley (1990), Shapiro and Willig (1990), Katz and Ordover (1990), and Choi (1993).

[4] This paper drew on theoretical literature such as Abreu et al. (1990) and Shapiro (1989), along with experimental evidence in Feinberg and Husted (1993).

[5] See Scott (1993), van Wegberg and van Witteloostuijn (1995), and Vonortas (2000).

[6] This is not the first attempt to model the effects of RJV on implicit collusion. Martin (1995) uses a tournament model to study the effect of RJVs, which achieve a process innovation for an existing product. His main result is that RJVs facilitate implicit collusion.

[7] We are grateful to Nicholas Vonortas for providing this data to us.

average (with mean HHI of 632 versus 727, and mean CR4 of 37 versus 40); (2) they are somewhat more capitalintensive, with a ratio of new capital expenditures as a percentage of value added at 7.6% compared to the all-manufacturing average of 6.2%; (3) within the group of industries engaging in significant RJV activity, we find a modest positive correlation (+0.15) across these industries between the percentage of companies involved in RJVs and their HHI, but a much stronger positive correlation (+0.71) between the percentage of companies involved in RJV and the ratio of new capital investment to value added; the latter result could be interpreted either as more research collaboration, where barriers to entry are higher, or as more of a tendency for RJVs where there is greater value of joint research to participating firms (sharing the relatively high-capital burden). An attempt to examine price trends, relative to overall PPI, for RJV-intensive industries was inconclusive.

At this level of aggregation, no clear patterns emerge between indicators of research collaboration and of output market structure. This suggests the need both for theoretical guidance (as pursued below) and intensive case-studies of particular research joint ventures (a goal for future research).

III. Previous Theoretical Work

In recent years, we have observed the development of new strategic coalitions in which firms cooperate in some domains and compete in others. An important aspect of the economics of these coalitions is that they create externalities (negative or positive) for nonmembers. At the same time new approaches to noncooperative game theory have been produced (e.g., Ray and Vohra, 1999; Bloch, 1995, 1996; Yi, 1997, 1998; Yi and Shin, 2000) providing a framework to analyze the endogenous formation of coalitions. Coalition formation has mainly been modeled as a two-stage game. In the first stage firms form a coalition and in the second stage engage in a noncooperative game (e.g., a Cournot or Bertrand oligopoly game) given the coalition structure formed in the first stage.

Although it is recognized that the spectrum of possible cooperative agreements is quite large, the theoretical literature on coalition formation has focused on two extreme forms of cooperation, collusive agreements and cost-reducing alliances. The most common example of a collusive agreement, creating positive externalities (for nonmembers within the industry), is an output cartel in oligopoly. Stigler (1950) realized that firms' incentives to free-ride on the cartels formed by other firms makes collusive agreements highly unstable. However, as Bloch (2002) points out, the final conclusion regarding the stability of a cartel depends on the rule of group formation.

Cartel formation in Cournot oligopoly has been studied by Salant et al. (1983). One of their main contributions was to determine the minimum profitable cartel size. A formal model of coalition formation was studied by Selten (1973) and D'Aspremont et al. (1983). Donsimoni (1985) studies cartel formation with a heterogeneous cost function, and Perry and Porter (1985) consider a model with conjectural variations.

As opposed to a collusive agreement, a cost-reducing alliance creates negative externalities for nonmember firms. Examples of cost-reducing alliances are alliances to develop new products, RJVs, and the joint use of facilities, just to name a few. As one can anticipate, the analysis of the formation of these alliances leads to different conclusions than the study of cartel stability. The analysis of cost-reducing alliances can be traced back to the literature on RJVs initiated by Katz (1986) and D'Aspremont and Jacquemin (1985) in the duopoly case. Yi (1998) and Yi and Shin (2000) propose general models of cost reducing alliances and RJVs.

The levels of cooperation and stability of the coalition structures (with either positive or negative externalities) have been analyzed under alternative models of group formation. Broadly speaking these models can be divided into two groups: those under an "Open Membership Rule", where players cannot exclude other players from joining the coalition (e.g., Selten, 1973; D'Aspremont et al., 1983; Bloch, 1995, 1996; and Yi and Shin, 2000), and those under an "Exclusive Membership Rule", where exclusion is allowed (e.g., Hart and Kurz, 1983; Bloch, 1996; Ray and Vohra 1999). Different rules of coalition formation lead to different predictions about the stability of the coalition structure.

Most of the studies of cartel formation in Industrial Organization assume that firms are ex ante symmetric, This is a strong assumption but often necessary as models of asymmetric firms are generally intractable. Bloch (2001) provides a selective survey of recent approaches to coalition formation in Industrial Organization, and offers a unified framework in which the different approaches can be compared. In this paper, we study cooperative agreements, both collusive and cost-reducing. We analyze the, stability of these coalition structures under both the Open Membership rule[8] and Exclusive Membership rules.

IV. Model and Results

The coalition formation games analyzed here share the main features of the frameworks proposed by Bloch (1996, 2002), Ray and Vohra (1999), Yi

[8] Given the US institutional context of the National Cooperative Research Act and vigorous antitrust enforcement, it seems implausible that members of cost-reducing alliances could refuse to admit new members.

(1997, 1998), and Yi and Shin (2000). Consider as a benchmark a standard Cournot oligopoly[9] with n firms and a linear inverse demand function[10]

$$P = 1 - Q.$$

Firms are ex ante symmetric and have identical marginal cost normalized at zero. Thus, each firm's optimal output choice is given by

$$y = \frac{1}{n+1}.$$

We then assume that firms have the opportunity to develop a new product that is expected to have the same demand function. If a firm decides to do so, it incurs a fixed cost[11] $M > 0$, with resulting profits

$$\pi = \frac{1}{(n+1)^2} - M,$$

where we assume

$$\frac{1}{(n+1)^2} \geq M.$$

This implies that all n firms could independently develop the new product.

We will then assume that firms may form a research consortium (cost-reduction alliance) and equally share the cost M to develop the new product.[12] In addition to deciding whether or not to join this cost-reduction alliance, firms will have to decide whether they want to form a collusive agreement (cartel) to reduce output and increase price. We will consider two possible membership rules. We start by assuming an open membership rule, presenting two approaches to the firms' decision problem. In the first

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[9] Note that the major results of our analysis hold in a Bertrand model as well (proofs available on request from the authors).

[10] For simplicity but without loss of generality, we used a linear demand function. The qualitative analysis does not change if a general demand function is considered.

[11] Unlike most of the literature on cost reduction alliances, we here assume that the research consortium does not affect firms' marginal cost, only reducing the fixed cost of development. This model could be extended to analyze a case in which in addition to the initial fixed cost the research consortium also has an impact on firms' marginal cost. While beyond the scope of this paper, this case seems to provide greater incentive for joint RJV/cartel formation under certain model specifications.

[12] Here, we assume that there are no fees to join the cost reduction alliances. This assumption is not unusual in the literature on group formation. However, if we were to consider a membership fee, in the equilibrium of the models that we analyze firms would have to evaluate the net benefit from joining the cost reduction alliance. We also assume, as is customary in the related literature, that there are no positive leakages. If we allow leakages to occur, we would have positive externalities. That is, firms would like the alliance to be formed but would prefer to be an outsider.

approach – game α – a firm decides whether to join a research consortia and a cartel sequentially. In the second approach – game β – decisions are taken simultaneously. That is, if a firm decides to join a coalition it will share the cost to develop the new product but is also making a commitment to participate in an output cartel.[13]

We next investigate how our results change if we assume an exclusive membership rule. Under this assumption firms would have veto power over the size of the coalition to be formed. We revisit game α and game β to see whether stable coalitions are formed.

1. THE COALITION GAME α UNDER OPEN MEMBERSHIP RULE

The coalition game α is set as a three-stage game. In the first stage firms jointly decide whether to form a research consortium. Then, in the second stage, regardless of the decisions taken in the first stage, firms jointly decide whether to form a cartel. Finally, in the third stage firms choose output. The group formation here follows the "Open Membership Rule"; that is, players simultaneously choose whether to join the coalition, and no member can be excluded. Thus, the firm's strategic space in both the first and second stage is $S = \{0, 1\}$, and the group (cost-reducing alliance and cartel) is formed by all firms choosing 1.

Let $1 \leq j \leq n$ be the number of consortia A_j formed in the first stage of the game, and a_i be the size of the consortium such that $1 \leq a_i \leq n$. Let $1 \leq K \leq n$ be the size of the cartel formed in the second stage of the game. A stable coalition (consortium or cartel) is defined as the Nash equilibrium outcome of the "cartel" and "consortium" sub-games. Moreover, a coalition is said to be stable if no member wants to leave the coalition and no outsider wants to join the coalition (see Bloch 2002).

Suppose that K firms form a cartel in the second stage of the game. As there are now $n - K + 1$ agents in the market, each of the $n - K$ independent agents obtains profits

$$\pi_i^I(a, K) = \frac{1}{(n - K + 2)^2} - \frac{M}{a_i}$$

for any value of a_i. However, members of the cartel equally share the total profits of the cartel. Hence, the profits of each firm in the cartel are given by

$$\pi_i^K(a, K) = \frac{1}{K(n - K + 2)^2} - \frac{M}{a_i}.$$

[13] While it is unclear how credibility of such a commitment would be achieved, especially in the presence of antitrust policy, we believe that it is useful to investigate the implications of these assumptions.

Notice that for any value of a_i, the profits of cartel outsiders are greater than the profits of insiders. It suggests that this cartel, if formed, may not be stable. To test this, we will follow the methodology suggested by Bloch (2002). In order for a firm to join a cartel its profit when a cartel exists must be greater or equal to its profits when no cartel is formed in the market. Salant et al. (1983) have shown that the minimal profitable cartel must contain 80% of the firms in the market, that is $K^* = 0.80n$. A cartel with less than 80% of the total number of firms in the market is not profitable for cartel members. Thus no cartel with $K < K^*$ will be formed.

In order to test if a cartel of size $K \geq K^*$ is stable we have to verify the external and internal stability of the cartel. The external stability test verifies whether outsiders have an incentive to join the cartel. The internal stability test verifies whether insiders have an incentive to leave the cartel. External stability will be tested following Bloch (2002). An outsider does not join a cartel if the maximal profit it would make by joining the cartel [in which case the grand coalition (full monopolization) is formed] is lower than it makes as an outsider. The profit of an outsider when a coalition is formed is given by

$$\pi_i^I = (K, a) = \frac{1}{(n-K+2)^2} - \frac{M}{a_i}.$$

If the grand coalition (full monopolization) is formed ($n = K$) the profit of a cartel member is given by

$$\pi_i^k = \frac{1}{4K} - \frac{M}{a_i}.$$

Hence,

$$\pi_i^I(n, a) > \pi_i^I(K, a)$$

for any $K \geq K^*$ and $n \geq 3$. According to the external stability condition, no outsider has incentive to join the coalition. Hence, the only relevant condition to check is whether insiders have an incentive to leave the cartel.

Assume that a cartel of size $K \geq K^*$ is formed. The profits of a cartel member are

$$\pi_i^K(K) = \frac{1}{K(n-K+2)^2} - \frac{M}{a_i}.$$

Suppose that one of insiders decides to leave the cartel and become an outsider. It is straightforward to see that cartel members (in a cartel of size K) will always get lower profits than an outsider when a cartel of size $K-1$ is formed. That is,

$$\pi_i^I(K-1) = \frac{1}{(n-K+3)^2} - \frac{M}{a_i} > \pi_j^K(K) = \frac{1}{K(n-K+2)^2} - \frac{M}{a_i}.$$

The stability of a cartel depends on the anticipations that firms form on the behavior of cartel members after they leave the cartel. Here, we use the Open Membership assumptions. In this case the coalition is not dissolved if a member departs. Thus, members of the cartel have incentive to leave, as they believe that the coalition would not cease to exist after its departure. This result applies to any homogeneous Cournot oligopoly and has been previously proven. According to Bloch (2002), in the Nash equilibrium of the cartel game no cartel formed is stable if $n \geq 3$ but a cartel will be formed and be stable if $n = 2$.

Moving to the first stage of the game, firms decide whether to form a consortium. As discussed before, no cartel is formed in the second stage; that is, all firms remain independent. Hence, in the first stage of the game,

$$\pi_i^I = \frac{1}{(n+1)^2} - \frac{M}{a_i},$$

where $1 \leq a_i \leq n$. It is straightforward to see that, under the open membership rule, all firms join the alliance and $a_i = n$. Cost-reducing alliances confer negative externalities on outsiders; thus all outsiders would have an incentive to join the alliance, and no insider would have an incentive to leave the alliance. Moreover, it is easy to see that members of a larger alliance enjoy higher profits as they benefit from a cost advantage with respect to competitors. For this reason, under the open membership rule only one cost-reduction alliance is formed.

2. THE COALITION GAME α UNDER EXCLUSIVE MEMBERSHIP RULE

Game α is now modified to include the assumption that firms have a veto power over the size of structure of the coalition to be formed in the second stage of the game (the cartel game). For the cartel game, we will use the sequential membership game proposed by Bloch (1996) and Ray and Vohra (1999). In these models players are forward-looking and take into account how their behavior affects the choices of other players.

The timing of the game is now as follows. In the first stage firms jointly (under the Open Membership rule),[14] decide whether or not to form a research consortium, as before. Then in the second-stage all n firms, regardless of the decision taken in the first stage, sequentially decide whether to form an output cartel. Finally, in the third-stage firms jointly choose output.

Notice that firms are ex ante identical and thus the game can be analyzed as a simple finite game with the following structure: first an exogenous rule is determined to identify in which order players will play. Then,

[14] Here we assume that the exclusive membership rule applies only to the cartel game.

the first player proposes a coalition of size K_1. The other players accept or reject the size of the coalition. If all firms accept, the coalition is formed. Otherwise the first firm to reject the offer makes a counter offer. Bloch (1996) solved this game and found that in the unique equilibrium of the sequential game of cartel formation (second-stage), the first $(n-K^*)$ firms remain independent and the last K^* firms form a cartel. The integer K^* is the first integer following $\left((2n+3)-\sqrt{(4n+5)}\right)/2$.

Bloch's result builds upon Salant et al. (1983). Salant et al. (1983) have shown that minimal profitable cartel size (K^*) in a linear Cournot model with homogeneous goods is 80% of the firms in the industry. Hence, in a sequential game of cartel formation, the first $n-K^*$ choose to remain independent and free-ride on the cartel formed by subsequent firms.

Thus, in the equilibrium of game α when firms choose sequentially whether to form a cartel (second-stage of the game), we have that all firms $(n=K)$ will join the research consortia but only K^* will form a cartel in the output market.

It is interesting to notice that when the decision on whether to form a research consortia and a cartel is taken separately firms always join the research consortia. The RJV does not, however, facilitate the formation of cartels. Whether or not a cartel is formed depends on the membership rule governing the cartel formation. Under the open membership rules, the cartel is not formed despite all firms having joined the cost reduction alliance. Under the exclusive membership rule a cartel is formed.[15] However, cartel formation is not facilitated by the existence of a cost reduction alliance.[16]

3. THE COALITION GAME β UNDER OPEN MEMBERSHIP RULE

Game β is set as a two-stage game. In the first stage, firms decide whether to join a coalition both to share the cost of developing a new product *and* to increase cooperation and market power. The decision on whether to join the coalition is taken simultaneously under an Open Membership rule. In the second stage, firms choose output.

[15] To some extent this result points out the limited applicability of the exclusive membership rule.

[16] As one would expect, these results hold even if we invert the model and have firms choosing first whether to form a cartel and then choosing to form a cost-reducing alliance. This follows from the assumption that the innovation does not affect firms' marginal cost. As mentioned before, a natural extension of this model is to assume that firms's marginal costs are also affected by the innovation. In such a scenario, we might find that the order in which the choices are made (alliance – cartel or cartel – alliance) might affect the outcome of the game.

If no coalition is formed and all firms stay independent, profits are given by

$$\pi^I(n) = \frac{1}{(n+1)^2} - M.$$

If K firms form a coalition such that there will be $(n-K+1)$ agents in the market, the profits of the outsiders are given by

$$\pi^I(K) = \frac{1}{(n-K+2)^2} - M.$$

The profits of each of the K firms inside the coalition are given by

$$\pi^K(K) = \frac{1}{K(n-K+2)^2} - \frac{M}{K}.$$

As in the previous model, we have to verify if a coalition will be formed and determine its stability. We start by defining the minimal size for which a coalition becomes profitable. Following Salant et al. (1983), we know that for a coalition to be formed the profits of a firm when a coalition exists must be greater or equal to the profits of a firm when no coalition is formed in the market. Thus there will be a cut-off rule such that:

$$K = K^{**} = 0.70Mn$$

(see Appendix A for proof).

Hence no cartel of size less than K^{**} will be formed. Notice that here the cut-off rule is a function of the innovation cost M. Moreover, K^{**} is lower than K^*, if and only if $M < 1.14$. But the latter holds by our assumption that $M \leqslant 1/(m+1)^2$. However, as M increases the minimum size of the profitable cartel increases as well.

If a coalition of size $K \geq K^{**}$ is formed, in order to test for external stability we need to check the incentive for outsiders to join the coalition. An outsider joins the coalition if the maximal profit by joining the cartel (in which case the grand coalition is formed) is higher than or equal to what it earns as an outsider. That is, if

$$\frac{K}{4} - \frac{M}{K} \geq \frac{1}{(n-K+2)^2} - M.$$

As we assumed that $M \leq 1/(n+1)^2$, for $n \geq 3$ outsiders join the coalition and the grand coalition is formed[17] and is stable if

$$\frac{4n}{36(n-1)} - \frac{n}{3} < M \leq \frac{1}{(n+1)^2}.$$

[17] When the external stability condition holds, it is not necessary to test the internal stability condition as it is trivial. If an insider leaves the cartel, it becomes an outsider, and outsiders have an incentive to join the cartel.

If $n = 2$ the necessary and sufficient condition for a coalition to be stable is that $M \leq 1/(n+1)^2$.

PROPOSITION 1. In the unique sub-game Nash equilibrium of the coalition game, if $n \geq 3$ the grand coalition is formed and is stable if $4n/36(n-1) - (n/3) < M \leq 1/(n+1)^2$. If $n = 2$, the grand coalition is always formed.

Proof. See Appendix. □

In game β there is a trade-off between the negative and positive externalities in the model. On the one hand, the larger the coalition the lower the cost to develop the new product. This would be an incentive to join the coalition. On the other hand, the larger the coalition the more negative is the impact on the revenue of the coalition's members; this might be an incentive to leave the coalition. What the model shows is that when M is sufficiently high the positive externality that firms would enjoy by staying out of the coalition is outweighed by the negative externality imposed on the outsiders. In this case, a coalition is formed and is stable. When M is sufficiently low, the effect is reversed, and the coalition is not formed.

It is interesting to observe that when the decisions on whether to join the cost-reduction alliance and to form a cartel are taken simultaneously the minimum size of a profitable cartel is reduced. We have shown that when the group formation includes a cost-reduction alliance and agreement to reduce output the 80% rule no longer applies.

3.1. *The Coalition Game β under Exclusive Membership Rule*

Now we assume that there is an exclusive membership rule. Thus the timing of the game is as follows: in the first stage firms decide sequentially whether to form a coalition. If formed, firms in this coalition will share the cost of developing a new product *and* form a cartel in the output market. The timing of the game is similar to the one discussed on Section IV.2.

PROPOSITION 2. In the unique sub-game Nash equilibrium of the sequential game β (exclusive membership rule), if $n \geq 3$ and $4n/36(n-1) - (n/3) < M \leq 1/(n+1)^2$ the first $(n - K^{**})$ firms remain independent and the last K^{**} firms form a coalition.

Proof. See Appendix. □

Here again, as in game β under the open membership rule, firms face a trade-off between the positive and negative externality. However, as firms have veto power they can maximize the benefit of sharing costs while minimizing the profit reduction caused by a large number of firms in the coalition.

Notice that the profit function of a coalition member is a concave function of its size. In the linear Cournot case and an alliance formed to reduce cost and output, its profits peak when 75% of the firms join the alliance and $4n/36(n-1)-(n/3)<M\leq 1/(n+1)^2$.

V. Conclusion

It is well known that instability is a limit to the formation of cartels. Thus, in order to explain the observed formation of cartels in some industries, we need to use a model that can show that the cartel members enjoy an advantage over outsiders. Examples of enriched models are Perry and Porter (1985), Farrell and Shapiro (1990), and Kamien and Zang (1990). They consider situations where the formation of cartels creates synergies so that the production cost of cartels members is lower than the cost of outsiders. In that case, a stable cartel size emerges. Another example is Nocke (1999), who studied the formation of cartels when firms face capacity constraints. Because cartels have access to more capacity, they enjoy an advantage when the individual capacity constraints are binding. Eerola and Näättänen (2004) have studied how strategic alliances to share production capacity affect market entry. They show that strategic alliances need not be anticompetitive; thus banning these alliances may lead to a more concentrated market structure.

Greenlee (2002) focuses on the welfare aspect of research sharing joint ventures. He shows that RVJs improve welfare when spillovers are low, and banning RJVs is beneficial for high spillovers. He also shows that when research sharing is imperfect and spillovers low, allowing only research sharing is the best industry-wide joint venture alternative for maximizing consumer surplus.

In our model, we examine whether RJVs provide enough synergy to make a cartel in the output market stable. We showed that this can be the case in the presence of simultaneous RJV and cartel decisions. Our results suggest, however, that only when a cartel is clearly tied to an RJV (model β) is it stable (and even then only for a sufficiently large fixed cost of product development). We find that by adding the synergy of a cost-reducing alliance the minimum size of a profitable cartel is reduced to approximately 75% of the firms in the market, pointing to potential anticompetitive aspects of RJVs.

We have also shown that the existence and stability of a cartel may be related to the membership rules assumed. Only in the case of the exclusive membership rule is a cartel formed in the second stage of game α. The stability of the cartel in this particular case is not related to the existence of RJV.

Future research into the relationship between RJVs and output cartels needs to go in two directions. First, the nature of explicit or implicit contracts required to sustain the collusive impacts of RJVs must be investigated. Second, as we expect the nature of competitive effects of cost-reduction alliances to vary by industry, we need to analyze empirically the outcomes of selected RJVs in an attempt to identify the factors that determine their performance.

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Appendix A

Proof. $K^{**} = 0.70Mn$.

Let the joint profits of the K colluding firms prior to the collusion be

$$\pi^{pc}(n, K) = K\left(\frac{1}{(n+1)^2} - M\right).$$

Let the joint profits of the K colluding firms after the collusion be

$$\pi^{ac}(n, K) = K\left[\frac{1}{K(n-K+2)^2} - \frac{M}{K}\right].$$

Following Salant et al. (1983) we construct a function $f(n, K)$ to determine the increase in profits caused by collusion of K firms in an industry of n firms.

$$f(n, K) = \pi^{ac}(n, K) - \pi^{pc}(n, K),$$
$$f(n, K) = \left[\frac{1}{(n-K+2)^2} - M\right] - K\left[\frac{1}{(n+1)^2} - M\right].$$

Since $f(\cdot, \cdot)$ is continuous and twice differentiable there exist at least one root $K^{**} > 0$ such that $f(n, K^{**}) = 0$.

Let $K^{**}(n)$ be the unique number of firms in the coalition that will lead to neither gain or loss. Let $\theta = K/n$ be the number of firms joining the coalition as a proportion of all firms in the industry. Thus the merge causes neither gain or loss if $\widehat{\theta} = K^{**}(n, M)/n$.

Let $K = \theta n$. Hence we have neither gain or loss if

$$f(n, \theta n) = 0,$$

$$f(n, \theta n) = \frac{1}{(n - \theta n + 2)^2} - M - \theta n \left[\frac{1}{(n+1)^2} - M \right],$$

$$f(n, \theta n) = \frac{(n+1)^2\{[n - \theta n + 2]^2[(1 - \theta n)M - M]\}}{(n - \theta n + 2)^2(n+1)^2},$$

where $f(n, \theta n) = 0$ when $(n+1)^2\{[n - \theta n + 2]^2[(1 - \theta n)M - M]\} = 0$. This is a cubic equation in θ and has three roots but only one root that is real.

We then calculate the minimum value of θ that makes $f(n, K) = 0$

$$\frac{\partial \widehat{\theta}}{\partial n} = 0.$$

Thus, $\widehat{\theta}(n, M)$ reaches a relative minimum at $n \simeq 5M$ and a maximum at $n \simeq -1M$. Hence for $n \geq 1, \theta(n, M) \geq \theta(5M) \simeq 0.70M$.

Proof of Proposition 1.

When the grand coalition is formed $n = K$. Keeping the strategy of the other firms constant, if one firm decides to leave the coalition, $K = n - 1$. Thus, we can write $1/4(n-1) - (M/n) \geq 1/(1+2)^2 - M$. Solving this inequality we have that the profit of an insider is greater than that of the outsider if $M > 4n/36(n-1) - (n/3)$. For $n = 2, 4n/36(n-1) - (n/3) < 0$ thus the necessary and sufficient condition for a coalition to be stable is that $M \leq 1/(n+1)^2$. Notice also that $\partial \pi_K^K / \partial K > 0, \partial \pi_K^{2K} / \partial K^2 \leq 0$. That is, π_K^K is U-shaped and convex. Thus either the grand coalition is stable and exists or no other coalition is stable.

Proof Proposition 2.

This proof follows Bloch (1996). Notice that $\partial \pi_K^K / \partial K > 0, \partial \pi_K^{2K} / \partial K^2 \leq 0$. If the profit function is U-shaped, there exits a minimal cartel size (K^{**}) for which firms prefer to form an alliance.

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