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Research Joint Ventures Cartelization with Asymmetric RDSpillovers

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Abstract

The paper analyzes the profitability of RDcooperation under asymmetric spillovers. It is shown that a firm prefers RDcompetition to RJV cartelization when its own spillover rate is low and the spillover rate of its competitor is high. While it prefers RDcartelization to RJV cartelization when the spillover rate of its competitor is sufficiently high. The equilibrium configuration is RJV cartelization for low spillover asymmetries, RDcompetition for intermediate asymmetries, and RDcartelization for high asymmetries.

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1. Introduction

The large literature on precompetitive R&D has mostly assumed that firms are symmetric. Yet, in the real world no two firms are alike: firms differ in size, technology, etc. Such asymmetries will affect how firms participate in technological cooperation, what they gain from it, and what threats it poses to them. One particular type of asymmetry between firms is asymmetry in R&D spillover levels. Differences in spillovers can be due to many factors: absorptive capacities (Cohen and Levinthal, 1989), the type of research conducted, inter-industry differences, differences in investments in secrecy, etc. Jarmin (1993:1) notes: "Geographical location, research and development expenditures and other idiosyncratic firm characteristics are likely to affect how individual firms learn from the experience of their rivals."

This paper analyzes R&D cooperation when firms have different levels of spillovers. The paper focuses on RJV cartelization, where firms coordinate R&D expenditures and share their research results. The profitability of RJV cartelization is analyzed, relative to both R&D competition and R&D cartelization (where firms only coordinate their R&D expenditures).

A few studies deal with different facets of asymmetries between firms. Atallah (2005a) analyzes R&D cartelization with asymmetric spillovers, and finds that R&D cooperation is profitable to both firms for a relatively limited range of spillovers: when spillovers are highly symmetric or highly asymmetric. He also shows that R&D cartelization increases total R&D investments iff the average spillover rate in the industry is sufficiently high. Amir and Wooders (2000) analyze unidirectional spillovers. De Bondt and Henriques (1995) and Amir and Wooders (1999) show that endogenous leader-follower roles arise due to asymmetric spillovers. Jarmin (1993) studies learning by doing and allows for differences in spillovers between firms. Kesteloot and Veugelers (1997) and Petit and Tolwinski (1999) allow for asymmetries in firm size and spillovers, but do not consider information sharing.[1]

The current note derives three main results. First, a firm prefers R&D competition to RJV cartelization if its (outgoing) spillover rate is sufficiently low and the spillover rate of its competitor is sufficiently high. Second, a firm prefers RJV cartelization to R&D cartelization when the spillover of its competitor is sufficiently low. Finally, the equilibrium configuration structure is (RJV cartelization, R&D competition, R&D cartelization) for (low, intermediate, high) spillover asymmetries.

2. The profitability of RJV cartelization

Two firms producing a homogeneous good compete à la Cournot. Demand is given by $p=A-y_1-y_2$, where y_i denotes the output of firm i. The marginal cost of firm i is given by

$$c_i = \alpha - x_i - \beta_j x_j \tag{1}$$

where α is the initial marginal cost, x_i is the R&D output of firm i, and $\beta_j \in [0,1]$ is the outgoing spillover rate from firm j to firm i. Profits are given by

$$\pi_i = (p - c_i) y_i - \gamma x_i^2 \tag{2}$$

[1] Other studies consider asymmetries in production costs: Atallah (2005b) and Baerenss (1999).

where γx^2 represents the convex costs of R&D.

The game has two stages: in the first stage firms invest in cost-reducing R&D, and in the second stage they compete in output. Solving backward, the solution to the output stage is

$$y_i = \frac{A - 2c_i + c_j}{3} \tag{3}$$

For the R&D stage, two scenarios are considered: R&D competition, where each firm chooses its R&D to maximize its own profits; and RJV cartelization, where firms choose their R&D investments to maximize joint profits, in addition to exchanging all information, that is, setting $\beta_1=\beta_2=1$. Under R&D competition, the equilibrium in R&D is given by

$$x_i^n = \frac{(A-\alpha)(2-\beta_i)(3\gamma+\beta_j(3-\beta_j)-2)}{27\gamma^2+(2-\beta_i)(2-\beta_j)(1-\beta_i\beta_j)-3\gamma[8-\sum_{k=1}^{2}\beta_k(4-\beta_k)]} \tag{4}$$

The s.o.c. is

$$\frac{\partial^2 \pi_i}{\partial x_i^2} = 2[\frac{(2-\beta_i)^2}{9} - \gamma] < 0 \tag{5}$$

Under RJV cartelization, the symmetric equilibrium is given by

$$x_i^c = \frac{2(A-\alpha)}{9\gamma - 4} \tag{6}$$

The s.o.c. is

$$\frac{\partial^2(\pi_1+\pi_2)}{\partial x_i^2}\Big|_{\beta_1=\beta_2=1} = \frac{2}{9}(2-9\gamma) < 0 \tag{7}$$

Substituting the solutions for R&D and output into (2) yields the equilibrium profits. Non-cooperation profits are given by

$$\pi_i^n = \frac{(A-\alpha)^2(9\gamma-(2-\beta_i)^2)(3\gamma+\beta_j(3-\beta_j)-2)\gamma}{[27\gamma^2+(2-\beta_i)(2-\beta_j)(1-\beta_i\beta_j)-3\gamma[8-\beta_i(4-\beta_i)-\beta_j(4-\beta_j)]]^2} \tag{8}$$

Cooperation profits are given by

$$\pi_i^c = \frac{(A-\alpha)^2\gamma}{9\gamma - 4} \tag{9}$$

The goal of this note is to compare cooperation with competition profits.

Proposition 1.[2] *Firm i prefers R&D competition to RJV cartelization when β_i is low and β_j is high, with the critical value of β_j increasing in β_i.*

[2]All proofs are in the Appendix.

Figure 1 shows how RJV cartelization affects profits. Consider for instance firm 1. Firm 1 gains from cooperation, except when β_1 is low and β_2 is high. In these circumstances, firm 1 prefers not to cooperate with firm 2. RJV cartelization involves both the coordination of R&D investments and perfect information sharing. When β_1 is low, cooperation implies a significant increase in β_1, which benefits firm 2 substantially. And when β_2 is high, the increase in β_2 (given by 1-β_2) is negligible, hence the gain to firm 1 is minor compared to the gain to firm 2, resulting in an improvement in the competitive position of firm 2.

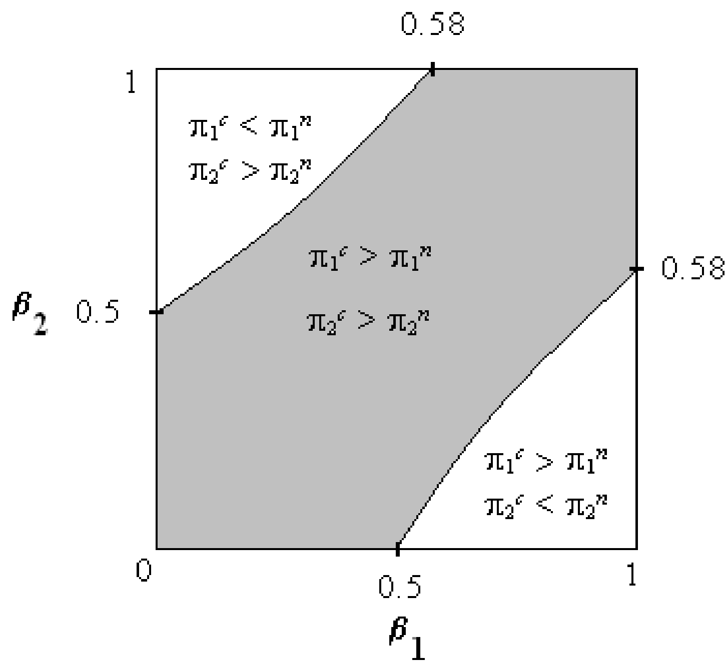


Figure 1. RJV cartelization vs. R&D competition

As for R&D expenditures, we know that R&D investments of both firms increase with the passage from R&D competition to RJV cartelization, and so does the effective cost reduction of each firm, which represents the dollar amount of cost reduction per unit of output. However, the increase in x_1 benefits firm 2 disproportionally, because of the significant increase in β_1. And the increase in x_2, although substantial (because firm 2 was initially investing less in R&D, due to its high spillover), does not benefit firm 1 as much, because the increase in β_2 is lower than the increase in β_1. By the same token, firm 2 prefers not to cooperate when β_2 is low and β_1 is high.

Figure 1 illustrates the spillover region where both firms prefer RJV cartelization to R&D competition. Outside this shaded region, RJV cartelization will not occur, because it is not profitable to one of the firms. Hence, the white areas of figure 1 represent regions where R&D cooperation is socially beneficial,[3] but does not take place because it is privately unprofitable.

[3]We know that RJV cartelization is always socially beneficial (unless there is overinvestment in R&D, which is not the case here) because it increases R&D investments and diffusion.

3. RJV cartelization vs. R&D cartelization

This model also allows us to analyze the profitability of RJV cartelization versus R&D cartelization.[4] Under R&D cartelization, firms coordinate their R&D expenditures, but don't share any information, hence the spillover rate is not affected by cooperation. Letting the first stage take place under R&D cartelization instead of RJV cartelization, yields the following investment in R&D:

$$x_i^{Rcar} = \frac{(A-\alpha)[\gamma(1+\beta_i)+\beta_j(1+\beta_i-\beta_i\beta_j)-1]}{9\gamma^2+(1-\beta_i\beta_j)^2-\gamma[10+\sum_{k=1}^{2}\beta_k(5\beta_k-8)]} \qquad (10)$$

Here we are interested in the difference π^{Rcar}-π^c.

Proposition 2. *Firm i prefers R&D cartelization to RJV cartelization when β_j is high, with the critical value of β_j increasing in β_i.*

Figure 2 illustrates the comparison between π_1^{Rcar} and π_1^c. We can see that firm 1 prefers RJV cartelization to R&D cartelization when β_2 is sufficiently low, and a lower β_2 is required the

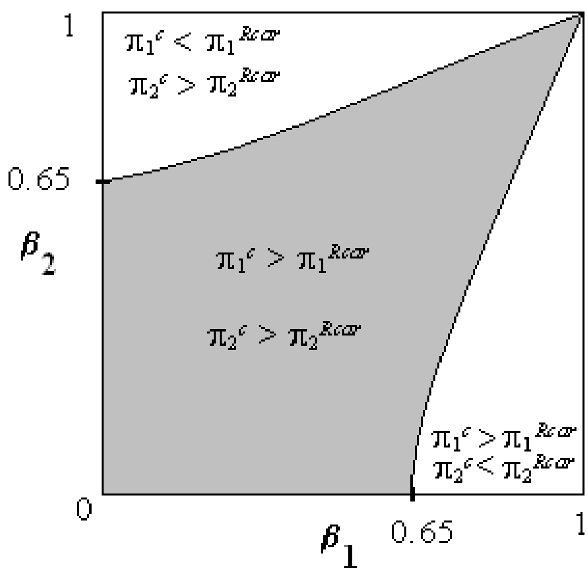


Figure 2. RJV cartelization vs. R&D cartelization

lower is β_1. The intuition is the same as for the comparison between R&D competition and RJV cartelization. The only difference between the two cooperative scenarios is that RJV cartelization involves information sharing, while R&D cartelization does not. Hence, when β_1 is high and β_2 is low, firm 2 is already benefitting substantially from the technology of firm 1, but firm 1 is not

[4] The detailed analysis of R&D cartelization with asymmetric spillovers, as well as the comparison of its profitability with R&D competition, has been performed in Atallah (2005a), and hence is not taken up here.

getting a substantial benefit from the diffusion of firm 2's technology; hence firm 1 prefers the shift to RJV cartelization, so that information sharing is equalized. Moreover, because R&D cartelization involves joint profit maximization, the region where R&D cartelization is preferred to RJV cartelization is larger than the region where R&D competition is preferred to RJV cartelization. By symmetry, firm 2 prefers RJV cartelization to R&D cartelization when β_1 is sufficiently low.

We can see from figure 2 that both firms prefer RJV cartelization in an area around the positively sloped diagonal, the width of which shrinks as spillovers increase. Outside this region, one of the firms would prefer R&D cartelization. Given that RJV cartelization is a "fuller" form of cooperation -because it involves an additional component, information sharing-, the agreement of both firms is likely to be required to shift from R&D cartelization to RJV cartelization. This agreement is unlikely to be obtained outside the shaded region in figure 2 (again, even though it is socially beneficial).

It is useful to contrast the effect of spillover asymmetries on the profitability of R&D cartelization (studied in Atallah, 2005a) vs. RJV cartelization (studied here), since these are the two main types of R&D cooperation studied in the literature. Figure 3 illustrates the regions where R&D cartelization is profitable to both firms under R&D cartelization (relative to R&D competition).

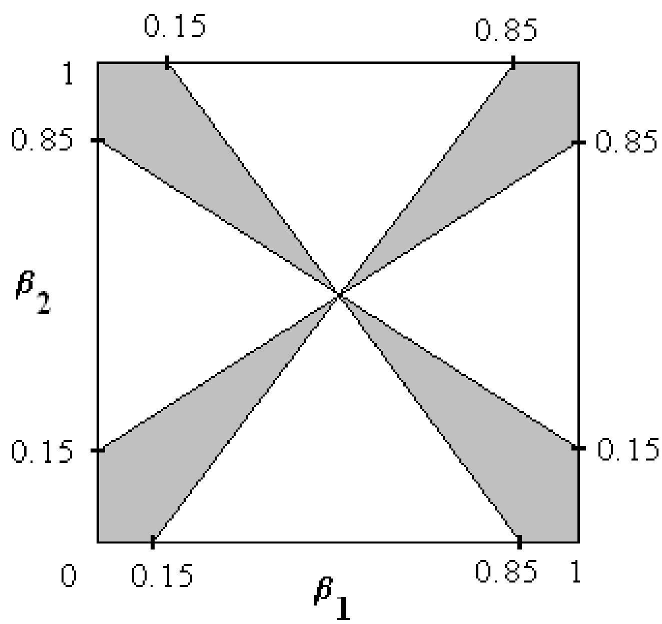


Figure 3. R&D cartelization vs. R&D competition

Shaded areas: $\pi_1^{Rcar} > \pi_1^n$ and $\pi_2^{Rcar} > \pi_2^n$

Source: Atallah (2005a)

Under R&D cartelization, cooperation is mutually beneficial when spillovers are either close to being symmetric or are very asymmetric. In contrast, with RJV cartelization (figure 1), cooperation is mutually beneficial in a spillover region around the positively sloped diagonal, that is, when spillovers are not "too asymmetric". Hence RJV cartelization is compatible with low or intermediate levels of asymmetries, while R&D cartelization is compatible with low or high degrees of asymmetries. Moreover, the region where RJV cartelization is mutually beneficial is much larger than the region where R&D cartelization is mutually beneficial. By allowing for information sharing and increasing diffusion and R&D, RJV cartelization creates a win-win situation and is sustainable for a wider range of spillovers. Whereas, by simply focusing on eliminating duplication, not encouraging diffusion, and sometimes reducing R&D (when the average spillover rate is sufficiently low), R&D cartelization is much more conflictual, and more sensitive to spillover asymmetries.

4. Equilibrium configuration

Putting these pieces of information together, we can predict what will be the equilibrium configuration for all spillover levels. The types of R&D interactions studied in this note differ by their ease of implementation. While the literature does not offer a precise definition of the ease of implementation, it is reasonable to expect that the more dimensions are involved in a type of cooperation, the harder it will be to implement, and more explicit agreement will be required of all participants. The easiest configuration to implement is R&D competition, since it requires no communication and no agreement. R&D cartelization is more complex than R&D competition, since it requires the coordination of R&D expenditures; but simpler than RJV cartelization, since the latter involves also information sharing. Henceforth, the agreement of both firms is required to switch from R&D competition to either R&D cartelization or RJV cartelization. Moreover, the agreement of both firms is required to switch from R&D cartelization to RJV cartelization.

The equilibrium concept used is noncooperative bargaining. This stage would precede the R&D and output stages. Figure 4 illustrates the bargaining structure. Firms have to choose the same type of cooperation in equilibrium, asymmetric outcomes do not make sense here. Firms start, by default, at R&D competition (this is the no agreement outcome). Firms determine whether they want to go from R&D competition to R&D cartelization. The agreement of both firms is required for this move, and each firm will agree to it iff it increases its profits. If yes, firms then determine whether they want to go from R&D cartelization to RJV cartelization or not; if both agree, the equilibrium is RJV cartelization, otherwise it is R&D cartelization. If the move from R&D competition to R&D cartelization is rejected by at least one of the firms, firms consider the option of moving from R&D competition to RJV cartelization. If both agree, RJV cartelization is the equilibrium, otherwise R&D competition is the equilibrium. This bargaining structure ensures that any move taken is mutually profitable to both firms.[5]

[5]The following is an alternative set of rules which leads exactly to the same outcomes:
-If R&D competition is the first choice of at least one firm, R&D competition is the equilibrium.
-If the first choices of both firms coincide, this choice is the equilibrium.
-Any choice that is ranked below R&D competition for any firm is eliminated, and the previous two rules are applied to the remaining choices.
-If one firm prefers R&D cartelization to RJV cartelization, while the other firm prefers RJV cartelization to R&D cartelization, and R&D competition is in third place for both firms, then the equilibrium is R&D cartelization.

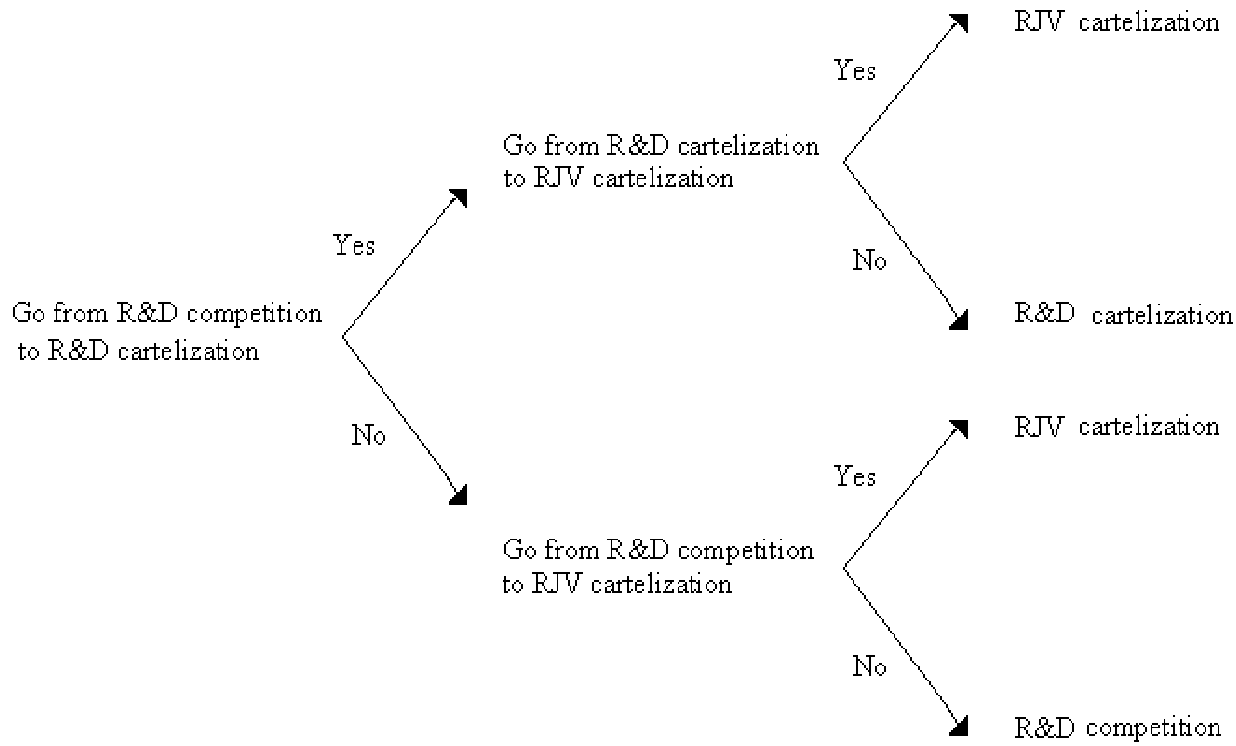


Figure 4. Bargaining structure

Figure 5 illustrates the equilibrium configurations in the spillovers' space. In the white regions, at least one of the firms prefers R&D competition to either R&D cartelization or RJV cartelization. Given that the other firm cannot "force" it to cooperate as R&D competition is the no agreement configuration, the equilibrium in these regions is R&D competition. In the black regions, both firms prefer R&D cartelization to R&D competition, and at least one of the firms prefers R&D cartelization to RJV cartelization. Hence firms agree to cooperate, but one firm is not interested in information sharing, and cannot be forced into it by the other firm; therefore, the equilibrium is R&D cartelization. In the grey regions, both firms prefer RJV cartelization to R&D competition and R&D cartelization, hence RJV cartelization is the equilibrium.

It can be seen from that figure that RJV cartelization is the equilibrium for relatively symmetric spillovers, R&D cartelization is the equilibrium for very asymmetric spillovers or when both spillovers are asymmetric but close to 1, while R&D competition is the equilibrium when the level of asymmetry is intermediate. There is a non-monotonic relationship between the complexity of R&D agreements and spillover asymmetries.

Proposition 3. *When firms choose between R&D competition, R&D cartelization, and RJV cartelization, the equilibrium is:*
-*RJV cartelization when the degree of asymmetry in spillovers is low;*
-*R&D competition when the degree of asymmetry in spillovers is intermediate;*
-*R&D cartelization when the degree of asymmetry in spillovers is high* (*and also when spillovers*

are asymmetric but close to 1).

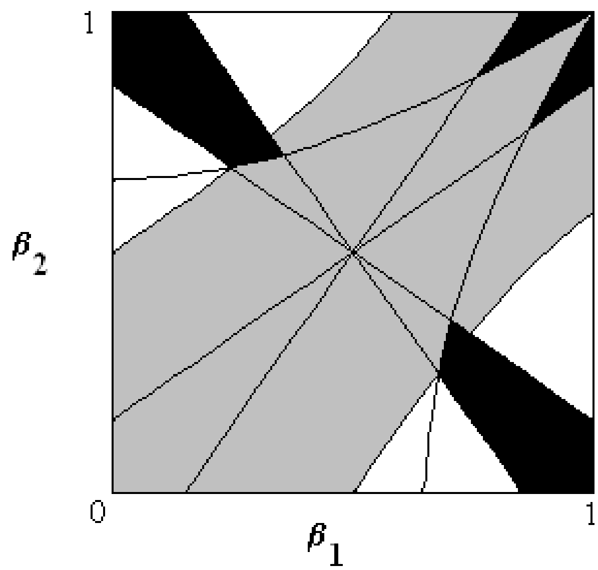
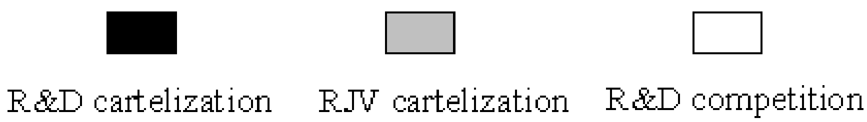


Figure 5. Equilibrium configurations



5. Conclusions

It was shown that a firm prefers R&D competition to RJV cartelization if its spillover rate is sufficiently low and the spillover rate of its competitor is sufficiently high. As for the comparison between RJV cartelization and R&D cartelization, a firm prefers RJV cartelization when the spillover of its competitor is sufficiently low. The equilibrium is (RJV cartelization, R&D competition, R&D cartelization) for (low, intermediate, high) spillover asymmetries.

Under symmetric spillovers, RJV cartelization is always preferred by all firms to both R&D competition and R&D cartelization. Neither of these results holds when spillovers are asymmetric. Moreover, there is a significant range of spillovers where firms don’t agree on R&D coordination and/or information sharing. Ongoing research by the author aims at developing more sophisticated information sharing schemes, which take into account initial asymmetries in spillovers, and which would make R&D cooperation incentive compatible for a wider range of spillovers.

Appendix

Proof of Proposition 1.

When comparing profits between any two settings, the s.o.c. must be satisfied for both settings. Moreover, from (6), the nonnegativity of x_i^c requires

$$\gamma > \frac{4}{9} \tag{11}$$

Consider the profitability of RJV cartelization relative to R&D competition for firm 1 for extreme spillover values.

$$(\pi_1^c - \pi_1^n)\Big|_{(0,0)} = \frac{12(A-\alpha)^2(3\gamma-1)\gamma}{(9\gamma-2)^2(9\gamma-4)} > 0 \tag{12}$$

$$(\pi_1^c - \pi_1^n)\Big|_{(1,1)} = \frac{9(A-\alpha)^2\gamma^2}{(9\gamma-2)^2(9\gamma-4)} > 0 \tag{13}$$

$$(\pi_i^c - \pi_i^n)\Big|_{(1,0)} = \frac{3(A-\alpha)^2\gamma[189\gamma(\gamma-1)+56\gamma-4]}{(27\gamma^2-15\gamma+2)^2(9\gamma-4)} > 0 \tag{14}$$

(12), (13), and (14) require $\gamma>4/9$, which is true by (11).

$$(\pi_1^c - \pi_1^n)\Big|_{(0,1)} = -\frac{(A-\alpha)^2\gamma[162\gamma^3-189\gamma^2+60\gamma-4]}{(27\gamma^2-15\gamma+2)^2(9\gamma-4)} < 0 \tag{15}$$

(15) requires $\gamma>2/3$. But this is true since

$$x_2^n\Big|_{(0,1)} = \frac{(A-\alpha)(3\gamma-2)}{27\gamma^2-15\gamma+2} > 0 \tag{16}$$

iff $\gamma>2/3$.

Similar conditions hold for firm 2, with the roles of β_1 and β_2 reversed. Equations (12) through (15), along with the continuity of the profit functions, imply Proposition 1.

Proof of Proposition 2.

The s.o.c. under R&D cartelization was not derived above, but it is easy to verify that it is given by

$$\frac{\partial^2(\pi_1+\pi_2)}{\partial x_i^2} = \frac{2}{9}[5+\beta_i(5\beta_i-8)-9\gamma] < 0 \tag{17}$$

We have that

$$(\pi_i^c - \pi_i^{Rcar})\Big|_{(0,0)} = \frac{3(A-\alpha)^2\gamma}{81\gamma^2-45\gamma+4} > 0 \tag{18}$$

because $\gamma>4/9$.

$$(\pi_1^c - \pi_1^{Rcar})\Big|_{(1,1)} = 0 \tag{19}$$

$$(\pi_1^c - \pi_1^{Rcar})\Big|_{(1,0)} = \frac{3(A-\alpha)^2(2\gamma-1)}{(9\gamma-4)(1+\gamma(9\gamma-7))} > 0 \tag{20}$$

which requires γ>1/2. But from (17)

$$\frac{\partial(\pi_1+\pi_2)}{\partial x_2^2}\Big|_{(1,0)} = \frac{10}{9} - 2\gamma < 0 \tag{21}$$

which implies γ>5/9.

$$(\pi_1^c - \pi_1^{Rcar})\Big|_{(0,1)} = -\frac{(A-\alpha)^2\gamma(3\gamma-1)}{(9\gamma-4)(1+\gamma(9\gamma-7))} < 0 \tag{22}$$

which requires γ>0.59. But this is true since

$$x_1^{Rcar}\Big|_{(0,1)} = \frac{(A-\alpha)\gamma}{9\gamma^2-7\gamma+1} > 0 \tag{23}$$

requires γ>0.59.
Similar conditions hold for firm 2, with the roles of β_1 and β_2 reversed. Equations (18), (19), (20), and (22) along with the continuity of the profit functions, imply Proposition 2.

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