

**”Endogenous technology sharing in R&D intensive industries” (Clark & Sand):  
Response to the referee**

We would like to thank the referee for several insightful comments and suggestions that have all been dealt with, and we hope that our answers to the referee’s comments are satisfactorily addressed in our comments and in the new version of the paper.

Although we do agree that the majority of the concerns raised by the referee do pose potential problems in terms of generality, and we do realise that we have some specific assumptions, these assumptions have been deemed necessary to be able to solve the model. In particular, we feel that these simplifications are necessary to be able to combine the literature on R&D and the literature on endogenous coalitions when introducing asymmetries. Without these simplifications solving for the equilibrium coalition becomes very difficult. In addition, although a number of the concerns certainly are valid concerns, they do not have significant qualitative effects on the results.

*Comment 1.a:*

In a previous version we have worked with a more asymmetric situation. In particular, the *ex post* marginal cost has been formulated as follows:  $\hat{c}_a = \theta_a c - x_a$  for the post R&D marginal cost without a coalition, and  $\hat{c}_i^{ij} = \theta_i c - x_i - x_j$  is the post R&D cost for firm  $i$  when in a coalition between firms  $i$  and  $j$ , and  $\hat{c}_k^{ij} = \theta_k c - x_k$  is the post R&D cost for the outsider.

Although this is a more general approach, the results with respect to the various technology sharing arrangements do not change qualitatively. In addition, we are not able to solve for the equilibrium coalition. In all of the coalition case considered, the simple relationship between quantities, R&D expenditure and profits is still present with the more asymmetric cost functions. This implies that a given firm’s profit is determined by the R&D expenditure by that particular firm. The analysis of the equilibrium R&D effort for, e.g., the coalition between the two most efficient firms reveals the following: An increase in the outsider’s efficiency parameter,  $\theta_k$ , causes a negative shift in  $k$ ’s R&D reaction function, and a positive shift in that of the insiders. Hence the insiders’ R&D increases whilst that of the outsider falls. Similarly, the outside firm devotes more resources to R&D when its rivals are less efficient

initially ( $\frac{\partial x_k^{ij}}{\partial \theta_i} = \frac{\partial x_k^{ij}}{\partial \theta_j} > 0$ ). Furthermore, the firm that is most efficient initially will undertake

more R&D than the less efficient partner, but since all technology advancements are shared among the coalition partners the gap in the R&D levels of the two inside firms is smaller than in the no-coalition case. The difference in R&D effort for the firms will, of course, depend on the specific relationship between the  $\theta$ ’s, but this is not qualitatively different from the results we obtain with the parameterization in the present version, and we judged the loss of generality as a result of our simplification to be minor in this respect. We hope that this answers the referee’s comment. See footnote 11.

*Comment 1.b:*

Our R&D cooperation involves a simple sharing of technology advancements without coordination of the R&D activities, which is an approach that has been coined “RJV competition” by Kamien, Müller & Zang (American Economic Review, 1992). This is one of the four models analysed in their work. Consequently, we feel that our formulation of the R&D cooperation is within the realm of the R&D literature, but we acknowledge the fact that a great number of papers on R&D incorporate cooperation also at the stage of deciding on

R&D expenditure. As mention in the Introduction “RJVs can take various forms, ranging from simple information sharing arrangements with non-cooperative investment decisions by separate R&D units, to fully integrated R&D units where investment decisions are made to maximize joint profits”. Our approach is also compatible with a number of technology sharing arrangements, among them the aircraft engine manufacturing example provided in the paper. This is acknowledged in the Concluding Remarks section.

*Comment 1.c:*

We follow the strand of literature on strategic R&D investments with d’Aspremont & Jacquemin (1988) being a seminal article, in which they model R&D costs as quadratic “reflecting the existence of diminishing returns to R&D expenditures” (d’Aspremont & Jacquemin, 1988). This convexity enables us to close the model. An alternative approach could be the one followed by Kamien, Müller & Zang (1992), in which they put restrictions on the R&D production function to guarantee the existence of equilibria. Consequently, we feel that our approach is well founded on established work in the field. However, the convexity naturally has some implications for our analysis. If costs were not convex, the cost saving from technology sharing would be lower (similarly for less than perfect spillovers), which may affect the welfare ranking of the various coalitions.

Allowing for limited spillovers, as opposed to the perfect spillovers analysed in our paper, may have implications for the predicted outcomes. It is possible to solve for the various coalitions we consider with less than perfect spillovers, but it turns out to be very difficult to solve for the endogenous coalition which is an important part of our analysis. The issue of less than perfect spillovers is mentioned in the last paragraph of the section “Technology sharing between the most efficient firms”. The main trade-off is the following: Less than perfect spillovers (between partners) would, ceteris paribus, reduce the effective cost reduction and moderate the increasing dominance effect. However, less than perfect spillovers also imply that the free-riding effect would be less dominant and work in the opposite direction. A potential effect on the ranking of welfare is mentioned in the section “Concluding Remarks”. With low spillovers, the value to society measured in terms of added consumers’ surplus is naturally lower. However, it is likely that even with very low spillovers firms would choose to join a coalition if it is costless to join, and if its cost advantage over its rivals is not deteriorated.

*Comment 1.d:*

Our approach is to analyse technology sharing where R&D efforts are complementary, and where firms do not coordinate on R&D effort. With this setting in mind, we do not entirely agree that it is more realistic to assume that coalitions affect fixed costs. However, we do agree that one argument for coordinating R&D expenditures often is to reduce socially wasteful R&D effort, which would provide an additional social gain from cooperation (often due to elimination of fixed costs of R&D). If technology sharing were to affect fixed costs, this would have potential impact through at least two different channels. First, fixed costs would affect entry/exit decisions by firms. However, we consider only equilibria in which all three firms are active. Second, changes to fixed costs will affect the difference in insider and outsider profits. This may affect the incentives for the outsider to break an existing coalition by offering one of the coalition partners a more attractive deal. However, the cost savings from entering into a coalition in our approach also affects the difference between outsider and insider profits (and the incentives to break the coalition). Since the endogenously chosen coalition is one which yields the highest industry profit, the result from our approach is likely to be (qualitatively) similar to a setting where coalitions affect fixed costs. Proposition 3 in

Horn & Persson (2001) may yield some insight, where it is stated that with fixed cost savings, the set of equilibrium coalitions are the structures with minimal industry cost. This is commented upon in the Concluding Remarks.

*Comment 1.e:*

Our intention has been to consider the simplest set up which would allow us to consider endogenous coalition formation, and this necessitates (at least) three firms. In addition, we wanted to consider a concentrated industry, which fits well with our aircraft engine manufacturing story. We do realise that this is not necessarily a good illustration for all industries. One obvious implication of the assumption of only three firms is that the concern posed in comment 2 (which is commented on below) related to what happens when deviant players depart is less of an issue. In less concentrated industries, there might be more than one decisive group, and it is thus reasonable to expect that the results will not be as strong. This is acknowledged in Horn & Persson (2001), in which they state that “it is difficult to derive results as strong as those in Propositions 1 and 2 for less concentrated structures, because of the intransitivity of the dominance relation”. We acknowledge this in the Concluding Remarks.

*Comment 1.f:*

We do agree that the issue of absorptive capacity should be addressed. In the literature on absorptive capacity and spillovers, with Kamien and Zang (2000) and Wiethaus (2005) as examples of this avenue of research, the main idea is that firms choose (endogenously) R&D approaches, idiosyncratic or broad approaches, which again have implications for the degree of spillovers. The degree of absorption of technology improvements may also depend on the initial technology (which may, of course, be the result of an endogenous choice). This is briefly mentioned in the Introduction in the new version.

*Comment 2:*

We do agree that understanding what happens to a coalition when one/some players depart is important. This is of particular importance when there are more than three players. In our setting with only three players, a two firm coalition will naturally break up if one of the firms departs and we are back in the no coalition scenario. In the three-firm coalition the issue becomes important. We realise that our explanation of the equilibrium coalition formation has been somewhat imprecise, and we have included a passage on the effect of players leaving the coalition in the section on Equilibrium Technology Sharing Arrangement. We do, however, feel that allowing potential partners full freedom to communicate and sign binding agreements to be a fairly accurate description of a number of technology sharing agreements (e.g., the aircraft engine manufacturing example).

*Comment 3:*

References to the articles by Barros (1998), and Goyal & Moraga-González (2001) are included in the paper (see the Introduction).

*Comment 4:*

We have considered an alternative, more condensed presentation of the computations. However, in our opinion both the propositions and the equilibrium R&D expressions in the various coalitions will have to be included. We have therefore chosen to leave the computations as is.

## *References*

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