Answer to the referee report 1

1)

As the referee observes, the reasons for the leadership behavior in the noncooperative case are not modeled in this paper. However, from the literature, we understand that such behavior can be justified; for example, Spence-Dixit model reviewed in Tirole (1988, pp. 314-323). Also, Shaffer (1995) provides some reasoning for the Stackelberg sequence. Our paper still presents just a theoretical possibility for such behavior which should be eventually tested empirically.

However, the question remains, why the leadership behavior is considered only in the noncooperative case, and not under collusion. In the case of collusion, the decision about the output levels is made jointly, so (under the assumption of linear costs) the cartel members may decide to split the monopoly profit in various proportions. Our assumption is that they split the profit evenly, but following the referee's idea that the leader could be entitled to a bigger share, the key conclusion of the paper still remains, i.e. the leader has now even more incentives to be in the cartel when the cooperation in R&D is tight.

Moreover, we agree with the referee that our results are to a significant extent driven by the assumption about the type of competition, but it was our objective to investigate the impact of this particular type of firms competition on the incentives to cartelize the industry.

In the case when the quantities are set simultaneously in the absence of any collusion (case d in the referee report 1), we obtain the following equilibrium values:

- the optimal R&D level of each firm:

$$x_i = \frac{2(a-c)(2-\beta)}{9b\gamma - 2(2-\beta)(1+\beta)}$$

- the optimal production volume of each firm:

$$q_i = \frac{3(a-c)\gamma}{9b\gamma - 2(2-\beta)(1+\beta)}$$

- the equilibrium market price of the final product:

$$p = \frac{6bc\gamma + a(3b\gamma - 2(2-\beta)(1+\beta)}{9b\gamma - 2(2-\beta)(1+\beta)}$$

- the equilibrium profit of each firm:

$$\pi_i = \frac{(a-c)^2\gamma(9b\gamma - 2(2-\beta)^2)}{(9b\gamma - 2(2-\beta)(1+\beta))^2}$$

Setting a=100, b=1, c=10, γ=10, we obtain the Cournot equilibrium values in the case of no collusion for various levels of parameter β. The results of calculations are given in table 1A.

Table 1A. Cournot equilibrium for $a = 100$, $b = 1$, $c = 10$, $\gamma = 10$ and $\beta \in [0,1]$.

$\boldsymbol{\beta}$	$\boldsymbol{x_i}$	$\boldsymbol{q_i}$	$\boldsymbol{p}$	$\boldsymbol{\pi_i}$
0,0	4,18605	31,3953	37,2093	898,053
0,1	3,98509	31,4612	37,0776	910,402
0,2	3,78151	31,5126	36,9748	921,545
0,3	3,57560	31,5494	36,9011	931,442
0,4	3,36763	31,5716	36,8569	940,059
0,5	3,15789	31,5789	36,8421	947,368
0,6	2,94668	31,5716	36,8569	953,349
0,7	2,73428	31,5494	36,9011	957,985
0,8	2,52101	31,5126	36,9748	961,267
0,9	2,30715	31,4612	37,0776	963,192
1,0	2,09302	31,3953	37,2903	963,764

Source: own calculations

The comparison of entries in the above table 1A with those of table 2 in the original paper leads to the conclusion that the profit of each firm in the case of Cournot competition without any cooperation (last column in table 1A) is lower than their profit in the case of full industry cartelization (last column in table 2 of the paper). Hence, no matter the level of spillovers, the firms prefer to form a full industry cartel rather than to compete on research as well as on production in the Cournot style. Thus it is a qualitatively different situation in comparison to the Stackelberg competition in the final product market considered in our paper.

2)

The referee is correct by saying that "a high externality does not imply 'per se' that joint decision on R&D has been made", but we have not claimed otherwise. Please observe that RJV is considered in both cases, i.e. when firm collusively decide about the level of R&D spendings, as well as, when the decision regarding these expenditures are made noncooperatively. By the way, we have adopted the interpretation of β=1 to be RJV by following Kamien et al. (1992).

The referee suggests solving the model by assuming cooperation at the R&D stage and no cooperation at the final product market level by maximizing joint profit (the sum of (10) and (11)) with respect to x_1 and x_2. We agree that such a procedure would be correct in the case of Cournot competition in the product market due to the symmetry of profits. However, we have serious doubts about this approach in the case of Stackelberg competition: why firms should be interested in maximizing the joint profits when the division of these profits will be asymmetric?

Following the referee's suggestion, we would obtain:

- the R&D levels of firms to be:

$$x_1 = \frac{(a-c)((2+\beta)b\gamma - 4(1-\beta)^2(1+\beta))}{4(1-\beta^2)^2 + b(-23+(40-23\beta)\beta)\gamma + 8b^2\gamma^2}$$

$$x_2 = \frac{(a-c)((1+2\beta)b\gamma - 4(1-\beta)^2(1+\beta)+)}{4(1-\beta^2)^2 + b(-23+(40-23\beta)\beta)\gamma + 8b^2\gamma^2}$$

- the production volumes of firms:

$$q_1 = \frac{2(a-c)\gamma(2b\gamma - 5(1-\beta)^2)}{4(1-\beta^2)^2 + b(-23+(40-23\beta)\beta)\gamma + 8b^2\gamma^2}$$

$$q_2 = \frac{2(a-c)\gamma(b\gamma - 3(1-\beta)^2)}{4(1-\beta^2)^2 + b(-23+(40-23\beta)\beta)\gamma + 8b^2\gamma^2}$$

- the market price of the final product:

$$p = \frac{4a(1-\beta^2)^2 - b(16c(1-\beta)^2 + a(7-\beta(8-7\beta)))\gamma + 2b^2(a+3c)\gamma^2}{4(1-\beta^2)^2 + b(-23+(40-23\beta)\beta)\gamma + 8b^2\gamma^2}$$

the profits of firms:

$$\pi_1 = \frac{(a-c)^2\gamma(4b(1-\beta)^2(29-\beta(44-27\beta))\gamma - 16(1-\beta)^4(1+\beta)^2 - 3b^2(28-\beta(52-27\beta))\gamma^2 + 16b^3\gamma^3)}{2(4(1-\beta^2)^2 + b(-23+(40-23\beta)\beta)\gamma + 8b^2\gamma^2)^2}$$

$$\pi_2 = \frac{(a-c)^2\gamma(8b(1-\beta)^2(10-\beta(15-11\beta))\gamma - 16(1-\beta)^4(1+\beta)^2 - b^2(49-92\beta+52\beta^2)\gamma^2 + 8b^3\gamma^3)}{2(4(1-\beta^2)^2 + b(-23+(40-23\beta)\beta)\gamma + 8b^2\gamma^2)^2}$$

Setting a=100, b=1, c=10, γ=10, we obtain the numerical values for various levels of parameter β. The results of calculations are given in table 2A.

Table 2A. R&D cooperation with joint Stackelberg profits maximized for $a = 100$, $b = 1$, $c = 10$, $\gamma = 10$ and $\beta \in [0,1]$.

β	x_1	x_2	q_1	q_2	p	π_1	π_2
0,0	2,81132	0,94077	47,0383	21,9512	31,0105	1074,83	477,431
0,1	2,56571	1,24136	46,9409	22,2785	30,7806	1068,81	488,628
0,2	2,64322	1,52605	46,9211	22,5668	30,5121	1065,86	497,617
0,3	2,73661	1,79997	46,9661	22,8274	30,2065	1065,46	504,891
0,4	2,84267	2,06683	47,0675	23,0682	29,8643	1067,27	510,784
0,5	2,95908	2,32949	47,2193	23,2949	29,4858	1071,05	515,518
0,6	3,08414	2,59020	47,4179	23,5114	29,0707	1076,67	519,239
0,7	3,21657	2,86088	47,6609	23,7208	28,6183	1084,05	522,037
0,8	3,35533	3,11317	47,9472	23,9251	28,1277	1093,17	523,953
0,9	3,49960	3,37861	48,2762	24,1260	27,5978	1104,06	524,990
1,0	3,64865	3,64865	48,6486	24,3243	27,0270	1116,78	525,110

Source: own calculations

Comparing the results of table 2A with those of table 1, our doubts about the maximization of joint Stackelberg profits with collusion at R&D stage are confirmed. For example, when $\beta = 0,9$ the profit of the leader is higher with R&D collusion (1104,06) than in the case of no collusion (1070,28), but the profit of the follower is lower with R&D collusion (524,99) than in the case of no collusion (536,46). Thus, it may happen that the leader prefers collusion at R&D stage whereas the follower does not, i.e. there is no reason for joint profit maximization.

3)

We agree that further analysis along the lines suggested by the referee would be definitely beneficial. However, it requires much more conceptualization, so our belief is that additional extensions could be left for future research.

References

Kamien, M. I., E. Muller, and I. Zang (1992). Research Joint Ventures and R&D Cartels. *The American Economic Review* 82: 1293-1306.
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