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R&D Cooperation and Industry Cartelization

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Abstract
The objective of this paper is to investigate the impact of R&D cooperation on cartel formation in the product market. The R&D investments that precede the production process are aimed at the reduction of the unit manufacturing costs, and could create positive externalities for the potential competitors. In contrast to the preceding literature, we assume that the competition between firms on the product market takes place according to the Stackelberg leadership model. For simplicity we focus on the case of duopoly. Numerical analysis shows that a closer cooperation at the R&D stage may strengthen the incentives to create a cartel in the product market.

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Keywords R&D cooperation of firms, industry cartelization, Stackelberg competition

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1 Introduction

The costs of research and development in many industries have exceeded the financial capabilities of individual enterprises for a long time. Even the biggest companies are not able to develop and implement new technologies on their own.[3] That is the reason why enterprises undertake various forms of cooperation in that area. One of such forms of cooperation is the research joint venture. Apart from the benefits arising from overcoming the cost barrier of conducting research and development, potentially, it can also help avoid unnecessary duplication of performed activities. Therefore, even if the expenditures made by an individual company participating in a joint venture were lower than those in the case of no cooperation, the technological progress could be attained at reduced costs, or its quality could be higher than in the case of companies operating independently. Acknowledging overall potential economic benefits, the European Commission has supported R&D cooperation among enterprises for many years.[4] Still, the question arises whether the facilitation of cooperation among companies at the R&D stage does not lead to a reduction of competition in the market product market, and in particular to the formation of a cartel in that market, which eventually could have negative effects on the consumer surplus and on the total welfare.

The purpose of this article is to examine how R&D cooperation influences the formation of cartels in the product market.[5] We consider a situation when the R&D expenditures that precede the production process of the firm, reduce the unit costs of production for that firm, but at the same time they may generate positive externalities for potential competitors. We will compare how various degrees of cooperation at the R&D stage affect the incentives of companies to form a cartel in the product market.

Similarly to the preceding literature, the analysis will be based on a two-stage game with two companies as players.[6] At the first stage, the firms simultaneously decide about the R&D expenditures, and at the second stage, they meet in the final product market.

Unlike the previous literature, it has been assumed that in the case of no cartel agreement in the final product market, the companies compete according to the Stackelberg leadership model. For simplicity, we focus on the case of a duopoly. Numerical analysis shows that closer cooperation at the R&D stage increases incentives for the companies to form a cartel in the final product market.

The paper is organized as follows. In the next section, the case of a noncooperative duopoly is analyzed, i.e. there is no cartel neither at the R&D stage nor in the final product market. In section 3, we consider the conduct and performance of companies that formed a cartel in the final product market and coordinated their R&D expenditures, i.e. they have fully cartelized the industry. Based on the comparison of the above two cases, the conclusions regarding the incentives for the companies to create a cartel will be given in section 4. Summary and final remarks close the paper.

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[3] See, e.g., Kaiser (2002).

[4] Examples of R&D cooperation of EU-firms in the IT industry that have been supported by various programmes of the European Commission can be found in van Wegberg (1995).

[5] An alternative to industry cartelization may be mergers and acquisition of enterprises. They were analyzed by Davidson and Deneckere (1984), and Mytelka (2005).

[6] The models in the form of such games were introduced by d'Aspremont and Jacquemin (1988), and De Bondt and Veugelers (1991). They have been further developed by Kamien et al. (1992).

2 Stackelberg competition

First consider an industry comprised of two firms, denoted 1 and 2. Firms manufacture q_1 and q_2 units of a homogeneous product, respectively. The market demand for the product is given as a linear price function:

$$p = a - bQ \ , \tag{1}$$

where p denotes the market price, $Q = q_1 + q_2$ is the volume of total production of the industry, while a and b $(a, b > 0)$ are given parameters.

Each of the companies is characterized by a linear function of the total manufacturing costs:

$$C_i\left(q_i, x_i, x_j\right) = (c - x_i - \beta x_j)q_i \ , \tag{2}$$

where c $(c < a)$ is a given parameter of an initial efficiency of firm i, x_i denotes the amount of R&D investments made by the company i, and x_j denotes the amount of R&D investments made by the competitor. Parameter β $(0 \leq \beta \leq 1)$ determines the size of R&D externalities, i.e. the benefits for a given company obtained as a result of research undertaken by the competitor, these are so called "knowledge spillovers".[7] Higher level of β means that the R&D investments made by one company allow the competitor to reduce the manufacturing costs by a greater amount for free.

The costs of the R&D investments have a form of quadratic function:

$$\gamma \frac{x_i^2}{2}, \tag{3}$$

where γ $(\gamma > 0)$ is a given parameter.

The entry barriers to the industry are viewed as too high for new enterprises to enter.

We assume that in this industry one company, say firm 1, plays the role of the Stackelberg leader, and the other one, say firm 2, is the follower. Thus, firm 1 is the first to set the level of its supply (q_1), and firm 2, given the production level set by the leader, decides about its own output level (q_2).

The game proceeds in two stages. At the first stage, both companies simultaneously and independently decide about their levels of R&D investments (x_i). These decisions affect the function of total manufacturing costs of each firm. At the second stage, the companies compete in the final product market according to the Stackelberg leadership model.

Consider the profit of the follower firm at the second stage of the game for a given amount of R&D investments, x_1 and x_2:

$$\pi_2 = (a - bQ)q_2 - (c - x_2 - \beta x_1)q_2 - \gamma \frac{x_2^2}{2}. \tag{4}$$

For a given output level of the leader (q_1), the follower maximizes its own profit by setting the production level at:

$$q_2 = \frac{a - c + x_2 + \beta x_1}{2b} - \frac{1}{2} q_1. \tag{5}$$

[7] See, e.g., Geroski (1995).

Taking into account the follower's reaction given by (5), the leader maximizes its own profit, with a given size of research x_1 and x_2:

$$\pi_1 = (a - bQ)q_1 - (c - x_1 - \beta x_2)q_1 - \gamma \frac{x_1^2}{2}. \tag{6}$$

The optimal production volume of the leader is given by:

$$q_1 = \frac{a-c+(2-\beta)x_1+(2\beta-1)x_2}{2b}. \tag{7}$$

Substituting (7) into (5), we obtain the optimal output level of the follower:

$$q_2 = \frac{a-c+(3\beta-2)x_1+(3-2\beta)x_2}{4b}. \tag{8}$$

The production levels q_1 and q_2 given by (7) and (8) constitute the Nash-Stackelberg equilibrium.

After substituting (7) and (8) into the inverse demand function given by (1), we obtain the equilibrium market price of the final product:

$$p = \frac{a+3c-(2+\beta)x_1-(2\beta+1)x_2}{4}. \tag{9}$$

At the first stage of the game, when enterprises simultaneously choose the amount of R&D investments, x_1 and x_2, the profits of firms may be written as:

$$\pi_1 = \frac{1}{8b}[a - c + (2-\beta)x_1 + (2\beta - 1)x_2]^2 - \gamma\frac{x_1^2}{2}, \tag{10}$$

$$\pi_2 = \frac{1}{16b}[a - c + (3\beta-2)x_1 + (3 - 2\beta)x_2]^2 - \gamma\frac{x_2^2}{2}. \tag{11}$$

The Nash equilibrium strategies at the first stage of the game are found as a solution to the following system of two equations with two unknowns x_1 and x_2:

$$\frac{\partial \pi_1}{\partial x_1} = 0, \tag{12}$$

$$\frac{\partial \pi_2}{\partial x_2} = 0, \tag{13}$$

which takes the form of:

$$[a - c + (2-\beta)x_1 + (2\beta - 1)x_2] - 4b\gamma x_1 = 0, \tag{14}$$

$$[a - c + (3\beta-2)x_1 + (3 - 2\beta)x_2] - 8b\gamma x_2 = 0. \tag{15}$$

Under certain restrictions on the value of parameters a, b, c, γ and β, the above system has exactly one solution in the following form:

$$x_1 = \frac{(a-c)(2-\beta)[2b\gamma-(1-\beta)(3-2\beta)]}{[8b\gamma-(3-2\beta)^2-2(2-\beta)^2]b\gamma+(3-2\beta)(2-\beta)(1-\beta^2)}, \tag{16}$$

$$x_2 = \frac{(a-c)(3-2\beta)[b\gamma-(1-\beta)(2-\beta)]}{[8b\gamma-(3-2\beta)^2-2(2-\beta)^2]b\gamma+(3-2\beta)(2-\beta)(1-\beta^2)}. \quad (17)$$

Substituting (16) and (17) into (10) and (11), we obtain the equilibrium profits of the leader and the follower:

$$\pi_1 = \frac{(a-c)^2\gamma[2b\gamma-(1-\beta)(3-2\beta)]^2[4b\gamma-(2-\beta)^2]}{2[8b\gamma-(3-2\beta)^2-2(2-\beta)^2]b\gamma+(3-2\beta)(2-\beta)(1-\beta^2)}, \quad (18)$$

$$\pi_2 = \frac{(a-c)^2\gamma[b\gamma-(1-\beta)(2-\beta)]^2[8b\gamma-(3-2\beta)^2]}{2[8b\gamma-(3-2\beta)^2-2(2-\beta)^2]b\gamma+(3-2\beta)(2-\beta)(1-\beta^2)}. \quad (19)$$

Due to a relatively vague algebraic form of the above solutions, we will use a simplified numerical analysis in order to show possibilities of certain outcomes. For the purpose of this paper, we will restrict our considerations to the case when four parameters of the model are: $a = 100$, $b = 1$, $c = 10$, and $\gamma = 10$. The results of the calculations for various levels of parameter β are given in table 1.

Table 1. Stackelberg equilibrium 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	4,81132	3,39623	48,1132	22,6415	29,2453	1041,70	454,97
0,1	4,56580	3,19106	48,0611	22,7933	29,1456	1050,70	468,62
0,2	4,31940	2,98030	47,9934	22,9254	29,0812	1058,40	481,16
0,3	4,07222	2,76467	47,9085	23,0389	29,0526	1064,70	492,58
0,4	3,82440	2,54483	47,8050	23,1348	29,0602	1069,53	502,84
0,5	3,57616	2,32137	47,6821	23,2137	29,1042	1072,85	511,93
0,6	3,32772	2,09487	47,5389	23,2763	29,1848	1074,60	519,84
0,7	3,07936	1,86587	47,3748	23,3233	29,3019	1074,77	526,57
0,8	2,83136	1,63487	47,1893	23,3553	29,4554	1073,33	532,11
0,9	2,58402	1,40237	46,9822	23,3729	29,6449	1070,28	536,46
1,0	2,33766	1,16883	46,7532	23,3766	29,8701	1065,61	539,64

Source: own calculations

Using table 1, let us consider the impact of parameter β, i.e. the extent of externalities in R&D, on the equilibrium behaviour of firms. When the external benefits for a given company resulting from the research undertaken by the rival are relatively small (parameter β is low), the R&D investments of each firm are relatively high and they decline with the growing scale of spillovers. It is not a surprise that the follower invests in R&D a smaller amount than the leader, because the latter derives relatively greater product market benefits. It is worth noticing that with the increase of β, the relative R&D effort of the leader in comparison to the follower increases; for $\beta = 0$, the ratio is approx. 4:3, and for $\beta = 1$ it becomes as much as 2:1.

When companies undertake R&D activities in a form of joint venture, the parameter β assumes the value of 1, which means the full internalization of spillovers. Since, in this version of the game, the cooperation at the R&D stage does not lead to a cooperation in the final product market, the decisions about the amount of R&D investments are made independently to maximize individual profits of each of the firms. At the same time it should be noticed from table 1 that R&D joint ventures lead to an overall decline in the efforts to reduce the costs of manufacturing.

Observe that leader's production level, q_1, decreases with the higher extent of spillovers, and it achieves its lowest value when companies form a joint venture. A reversed relationship takes place in the case of the follower: its production volume, q_2, increases with the higher amount of spillovers and achieves the largest value when the companies form a joint venture. The total market supply, $(q_1 + q_2)$, initially increases (for low values of the parameter β), and afterwards (for larger β) declines, and achieves its lowest value when the companies form a joint venture. This in turn influences the level of the market price, which becomes the highest when companies undertake R&D activities within a joint venture; thus the consumers will not be pleased with such behaviour of producers.

The profits of individual firms, as it could have been expected, do not change fluctuate in the same way for the leader and for the follower. On the one hand, the leader's profits initially go up with an increase of the parameter β, but when this parameter exceeds 0,7, the economic performance of the leader starts deteriorating. On the other hand, the follower's profits keep rising continuously, together with an increase of β, and they achieve their maximum when the companies form a joint venture. Thus, in the case of the Stackelberg competition, a joint venture is beneficial for the follower, but less beneficial for the leader, who would rather limit the scale of spillovers.

Now, we move on to analyze the case of firms' cooperation within a cartel.

3 Full cartelization of the industry

For the sake of comparison, we now consider a model proposed by d'Aspremont and Jacquemin (1988), in which the companies have formed a cartel both at the stage of R&D, and at the final product market. We assume that the demand function as well as the cost functions of the firms are the same as in the previous section.

At the second stage of the game, the companies choose the production levels q_1 and q_2 to maximize their joint profit, given the amount of R&D investments, x_1 and x_2:

$$\pi = (a - bQ)Q - (c - x_1 - \beta x_2)q_1 - (c - x_2 - \beta x_1)q_2 - \gamma \frac{x_1^2}{2} - \gamma \frac{x_2^2}{2}. \qquad (20)$$

At the symmetric equilibrium, i.e., $x_1 = x_2 = x$, the optimal production level of each firm in the cartel is:

$$q = q_1 = q_2 = \frac{a - c + (1+\beta)x}{4b}. \qquad (21)$$

Thus, after substituting (21) into the inverse demand function given by (1), we obtain the equilibrium price in the final product market as:

$$p = \frac{a + c - (1+\beta)x}{2}. \qquad (22)$$

At the first stage of the game, when companies simultaneously choose x_1 and x_2, their joint profit becomes:

$$\tilde{\pi} = \frac{1}{4b}[a - c + (1+\beta)x]^2 - \gamma x^2. \qquad (23)$$

When the firms cooperate within a cartel, both in the R&D activities and in the final product market, the symmetric equilibrium arises when the research investments of each of the companies are:

$$\tilde{x} = \frac{(a-c)(1+\beta)}{4b\gamma-(1+\beta)^2}, \tag{24}$$

and the production level of each of the firms, after substituting (24) into (21), is:

$$\tilde{q} = \tilde{q}_1 = \tilde{q}_2 = \frac{(a-c)\gamma}{4b\gamma-(1+\beta)^2}. \tag{25}$$

From (23) it follows that the profit of each of the firms in the situation of full cartelization of industry becomes:

$$\tilde{\pi}_1 = \tilde{\pi}_2 = \frac{(a-c)^2\gamma}{4b\gamma-(1+\beta)^2}. \tag{26}$$

For the sake of a comparison with the results obtained in the previous section, we will limit our numerical analysis to the case when the four parameters are $a = 100$, $b = 1$, $c = 10$, and $\gamma = 10$. The results of the calculations for various levels of parameter β have been presented in the table 2.

Table 2. Full cartelization equilibrium for $a = 100$, $b = 1$, $c = 10$, $\gamma = 10$, and $\beta \in [0,1]$

$\boldsymbol{\beta}$	$\tilde{\boldsymbol{x}}$	$\tilde{\boldsymbol{q}}_{\boldsymbol{i}}$	$\boldsymbol{p}$	$\tilde{\boldsymbol{\pi}}_{\boldsymbol{i}}$
0,0	2,30769	23,0769	53,8462	1038,46
0,1	2,55220	23,2019	53,5963	1044,08
0,2	2,80083	23,3402	53,3195	1050,31
0,3	3,05403	23,4926	53,0149	1057,17
0,4	3,31230	23,6593	52,6814	1064,67
0,5	3,57616	23,8411	52,3179	1072,85
0,6	3,84615	24,0385	51,9231	1081,73
0,7	4,12288	24,2522	51,4956	1091,35
0,8	4,40696	24,4831	51,0337	1101,74
0,9	4,69909	24,7321	50,5359	1112,94
1,0	5,00000	25,0000	50,0000	1125,00

Source: own calculations

Using table 2, let us consider the equilibrium behaviour of firms, for various levels of the parameter β, i.e. the size of spillovers. In the case of full cartelization of the industry, together with the increase in the scale of R&D externalities, there is also an increase in research investments of individual companies aimed at the marginal cost reduction of final product manufacturing. At the same time, we observe an increase in the supply of final products offered by each of the firms. That results in price reductions of the manufactured products when the amount of spillovers increases. Finally, the profits of each firm operating within a fully cartelized industry increase monotonically together with the growing extent of R&D externalities.

In a fully cartelized industry, the companies achieve the highest profits when R&D activities are performed within a joint venture, i.e., the parameter β assumes the value of 1, which means the full internalization of R&D spillovers.

4 Incentives for cartelization

Comparing the results of table 1 and table 2, we may draw final conclusions regarding the incentives for industry cartelization. When the benefits for an individual company from the research performed by a rival are relatively low ($\beta < 0{,}5$), the profits gained by the

Stackelberg leader (the second to last column in table 1) are higher than the firm profits in a fully cartelized industry, i.e. when firms cooperate at the R&D stage and in the final product market (the last column in table 2). Thus, when the level of spillovers is relatively low, the company that may assume the role of the Stackelberg leader will not be interested in forming a cartel in this industry.

However, when the level of R&D spillovers is considerable ($\beta > 0{,}5$), the comparison of profits for the Stackelberg leader with the profits gained by a company in the cartelized industry shows that none of the firms will have any incentives to stay outside of the cartel. Moreover, the firms earn the biggest profits when they coordinate their R&D investments and production quantities within a full industry cartel, and at the same time form an R&D joint venture in order to fully internalize the spillovers. As a result it could be expected that R&D cooperation of firms raises the risk of industry cartelization. That creates a greater regulatory challenge for the antitrust authorities.

Thus the basic result of the above considerations is the conclusion that the tightening of cooperation at the R&D stage may create sufficient incentives for companies to fully cartelize the industry. It means that the buyers of the final products in this industry could be harmed. Even though joint efforts of the cartel participants to reduce manufacturing costs will contribute to lower market prices for the final products (second to last column in table 2), nevertheless the goods will be still much more expensive in comparison to prices when the companies compete according to the Stackelberg model. Hence, serious challenges for the economic policy may emerge.

Concluding remarks

In this paper, we compared the performance of firms under various forms of R&D cooperation and for different types of behaviour in the final product market. The comparison shows that together with an increasing size of R&D spillovers, the firm that becomes the Stackelberg leader in the final product market may earn lower profits than if it creates a full cartel with its rival in a given industry. Since the maximum level of spillovers is achieved when companies form an R&D joint venture, the incentives to create a full industry cartel are the strongest in this case. It should also be noted that such cartel is stable.

We should emphasize that in the textbook models of oligopoly, in which the R&D stage is not considered, a cartel formed in the product market allows each of the companies to earn profits identical to the level gained by the Stackelberg leader. It means that in those models a company is indifferent between behaving noncooperatively by playing the role of the Stackelberg leader, or behaving cooperatively by forming a cartel with its rival. Thus, the incorporation of the R&D stage into the analysis of oligopoly generates qualitatively different results.

The conclusions presented in this paper are largely based on a limited numerical analysis. Thus, as the next step, it is necessary to determine the robustness of our results to the fluctuations of the key parameters of our model.

Among the directions of future research regarding the impact of R&D cooperation on the industry cartelization, other types of cost functions and different forms of competition among firms could be considered; for example, in the articles on market cartelization, Prokop (1999, and 2011) considers quadratic cost functions in the price leadership model. In addition, the comparative analysis might be extended to the case of potential mergers among the industry participants.[8]

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[8] This direction of research has been initiated by van Wegberg (1995).

References

d'Aspremont, C. and A. Jacquemin (1988). Cooperative and Noncooperative R&D in Duopoly with Spillovers. *American Economic Review* 78: 1133-1137.
http://ideas.repec.org/a/aea/aecrev/v78y1988i5p1133-37.html

Davidson, C. and R. Deneckere (1984). Horizontal Mergers and Collusive Behavior. *International Journal of Industrial Organization* 2: 117-132.
http://ideas.repec.org/a/eee/indorg/v2y1984i2p117-132.html

De Bondt, R. and R. Veugelers (1991). Strategic Investment with Spillovers. *European Journal of Political Economy* 7: 345-366.
http://ideas.repec.org/a/eee/poleco/v7y1991i3p345-366.html

Geroski, P. (1995). Do spillovers undermine the incentive to innovate? In S. Dowrick (Ed.), *Economic approaches to innovation*. Aldershot: Edward Elgar.

Kaiser, U. (2002). An empirical test of models explaining research expenditures and research cooperation: evidence for the German service sector. *International Journal of Industrial Organization* 20: 747 – 774.
http://ideas.repec.org/a/eee/indorg/v20y2002i6p747-774.html

Kamien, M. I., E. Muller, and I. Zang (1992). Research Joint Ventures and R&D Cartels. *The American Economic Review* 82: 1293-1306.
http://ideas.repec.org/a/aea/aecrev/v82y1992i5p1293-306.html

Mytelka, L. K. (1995). Dancing with Wolves: Global Oligopolies and Strategic Partnerships. In J. Hagedoom (ed.), *Technical Change and the World Economy: Convergence and Divergence in Technology Strategies*. Aldershot: Edward Elgar.

Prokop, J. (1999). Process of dominant-cartel formation. *International Journal of Industrial Organization* 17(2): 241-257.
http://ideas.repec.org/a/eee/indorg/v17y1999i2p241-257.html

Prokop, J. (2011). Powstawanie i stabilność karteli heterogenicznych. *Gospodarka Narodowa* 80/21(10): 39-57. http://ideas.repec.org/p/pra/mprapa/43712.html

van Wegberg, M. (1995). Can R&D alliances facilitate the formation of a cartel? The example of the European IT industry. Research Memoranda 004, Maastricht : METEOR, Maastricht Research School of Economics of Technology and Organization.
http://ideas.repec.org/p/dgr/umamet/1995004.html