Available online at www.sciencedirect.com
ScienceDirect
Procedia Economics and Finance 14 (2014) 507 – 514
Procedia Economics and Finance
www.elsevier.com/locate/procedia

International Conference on Applied Economics (ICOAE) 2014

Research Joint Ventures and Cartelization of Industries

Jacek Prokop*

Department of Economics, Warsaw School of Economics, Al. Niepodległości 162, Warsaw 02-554, Poland

Abstract

The aim of this paper is to investigate the impact of the firms' behavior in the product market on their decisions at the R&D stage. We compare the consequences of the Stackelberg-type competition of two firms for the R&D investments with the situation of a cartelized industry under the assumption of quadratic cost functions. Numerical analysis shows that the lowest values of R&D efforts occur when the companies form a research joint venture. Moreover, greater R&D expenditures can be observed when a research joint venture is formed in a cartelized industry rather than under a Stackelberg-type duopoly.

Selection and/or peer-review under responsibility of the Organizing Committee of ICOAE 2014

Keywords: **research joint ventures; duopoly; cartelization of industries; quadratic cost functions**

1. Introduction

R&D cooperation of firms in the high-tech industries is widespread. It takes place within institutionalized frameworks of special consortia, as well as in an informal way through the exchange of information between employees of different companies. As a result, the investments of one company to improve technology and to reduce the costs of production create positive externalities (knowledge spillovers) for the other firms in the industry by helping them to decrease their manufacturing costs.[†] The extent of spillovers becomes the largest in the case of research joint ventures, which allow for a complete mutual exchange of technological advancements.

* Corresponding author. Tel.: +4822-564-8633; fax: +4822-646-6115.
E-mail address: jacek.prokop@sgh.waw.pl.
[†] See, e.g., Geroski, 1995.

Selection and/or peer-review under responsibility of the Organizing Committee of ICOAE 2014
doi:10.1016/S2212-5671(14)00742-4

Research joint ventures may help eliminate duplication of activities and allow for technological improvements at the lower investment expenditures. The creation of a research joint venture, or the existence of a less formal exchange of knowledge and experience does not determine the extent of efficiency-enhancing investment outlays of individual firms. Companies may decide about the size of their expenditures in a noncoordinated way, or could jointly set the level of research spending by forming an R&D cartel.

The situation in a given industry depends, also, on the type of competition in the market for the final good. The same firms, that undertake cooperation at the R&D stage, may apply different scope of coordination for their behavior on the final product market. Among a variety of possible actions, we may consider noncooperative, or collusive behavior of companies at the sales stage.

The aim of this paper is to investigate the impact of the firms' behavior in the final product market on their decisions at the R&D stage, with a special consideration of research joint ventures. We first analyze the Stackelberg-type competition of firms on the market, and identify the consequences of such noncooperative rivalry for the R&D decisions. Next, we consider the impact of cartel creation on the R&D investments, and compare it with the noncollusive situation.

Analogously to the models introduced by d'Aspremont and Jacquemin, 1988, and by De Bondt and Veugelers, 1991, the analysis is conducted in a two-stage game with two firms as players. In the first stage, the companies simultaneously choose the level of R&D investments, and in the second stage they meet on the market for the final good. However, the type of noncooperative behavior analyzed by these authors has been limited to the Cournot model.[‡]

In this paper, we extend the analysis by introducing the Stackelberg competition in the product market. Unlike the previous literature, we assume that the production process is characterized by the quadratic cost functions, rather than the linear ones, i.e. the marginal costs are increasing.[§] We investigate whether the replacement of the linear costs by a quadratic function will have any impact on the key conclusions about the behavior of firms in the R&D stage. Since the algebraic solutions to the models discussed in this paper are hard to obtain, we limit our considerations to a numerical analysis.

The rest of the paper is organized as follows. The next section focuses on the noncooperative competition of duopolists in the case of Stackelberg leader-follower behavior in the final product market. In section 3, we consider the conduct and performance of firms in a fully cartelized industry, i.e., in the case of collusion at the R&D stage as well as in the final good market. Based on the comparison of the above cases, we formulate conclusions regarding the cost-reducing investments of firms in section 4. The paper ends with a brief summary and conclusions.

2. Quantity leadership

Consider an industry with two firms, denoted 1 and 2. Each firm i $(i = 1, 2)$ manufactures q_i units of an identical product. An inverse demand function for the good is given in a linear form:

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

where p denotes the market price, Q $(= q_1 + q_2)$ is the total quantity demanded, and a $(a > 0)$ is a given parameter.

[‡‡] These models have been further developed by, e.g., Kamien et al., 1992, who also considered the case of Bertrand competition.

[§] The Stackelberg competition in the context of R&D investments and cartelization of industries has been first considered by Prokop and Karbowski, 2013. These authors, however, assumed the linear cost functions.

The manufacturing costs of firm i are characterized by a quadratic function in the following form:

$$C_i(q_i, x_i, x_j) = \frac{{q_i}^2}{c+x_i+\beta x_j}, \tag{2}$$

where c $(c < a)$ is a given parameter of an initial efficiency of each firm, 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 other firm. Parameter β $(0 \leq \beta \leq 1)$ describes the size of research externalities, i.e. the benefits for a given company obtained as a result of R&D undertaken by the competitor. Higher level of β means that investments in R&D made by one firm have a greater impact on cost reduction of the competitor.

Firm i incurs the costs of R&D investments according to the following quadratic function:

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

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

We assume that there is no issue of entry to this industry.

Initially, we consider the case when the competition of firms in this industry is characterized by quantity leadership in the final product market, i.e., firm 1, plays the role of the Stackelberg leader, and firm 2, is the follower. Thus, firm 1 is the first to set the level of its output, q_1, and firm 2, knowing the production level chosen by the leader, decides about its own level of supply, q_2.

There are two stages of decision making by firms. At the first stage, both of them simultaneously and independently choose their levels of research investments, x_i. These decisions affect the levels of manufacturing costs of each firm. At the second stage, the companies meet in the final product market and behave according to the Stackelberg leadership model.

In order to find equilibrium of the above game, we first consider the profit of the follower firm at the second stage for a given amount of research investments, x_1 and x_2:

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

Given the output level of the leader, q_1, the follower firm maximizes its own profit by setting the production level at:

$$q_2 = \frac{(a-q_1)(c+\beta x_1+x_2)}{2(1+c+\beta x_1+x_2)}, \tag{5}$$

which is calculated by solving the first order optimality condition $\frac{\partial \pi_2}{\partial q_2} = 0$ with respect to q_2.

Taking into account the reaction function of the follower described by (5), the leader maximizes its own profit for given levels of research investments x_1 and x_2:

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

Thus, the profit given by (6) can be rewritten as a function of one variable, i.e., q_1:

$$\pi_1 = \frac{q_1(a-q_1)(2+c+\beta x_1+x_2)}{2(1+c+\beta x_1+x_2)} - \frac{q_1^2}{c+x_1+\beta x_2} - \frac{1}{2}\gamma x_1^2. \tag{7}$$

From the first order condition for profit maximization, $\frac{d\pi_1}{dq_1} = 0$, the optimal output level for the leader is

$$q_1 = \frac{a(2+c+\beta x_1+x_2)(c+x_1+\beta x_2)}{2\left((2+c+\beta x_1+x_2)(c+x_1+\beta x_2)+2(1+c+\beta x_1+x_2)\right)}. \quad (8)$$

By substituting (8) into (5), we obtain the optimal output of the follower:

$$q_2 = \frac{a(c+\beta x_1+x_2)\left((2+c+\beta x_1+x_2)(c+x_1+\beta x_2)+4(1+c+\beta x_1+x_2)\right)}{4(1+c+\beta x_1+x_2)\left((2+c+\beta x_1+x_2)(c+x_1+\beta x_2)+2(1+c+\beta x_1+x_2)\right)}. \quad (9)$$

The outputs q_1 and q_2 given by (8) and (9) constitute the Nash-Stackelberg equilibrium for given levels of research investments, x_1 and x_2.

After substituting (8) and (9) into (4) and (7), we obtain the profits of each firm, π_1 and π_2, as functions of R&D investments, x_1 and x_2.

In the first stage of the game, when companies simultaneously decide about their research investments, x_1 and x_2, the Nash equilibrium strategies are obtained as a solution to the following set of two equations in two unknowns, x_1 and x_2:

$$\frac{\partial \pi_i}{\partial x_i} = 0, \quad i = 1, 2. \quad (10)$$

Under certain conditions satisfied by the parameters a, c, γ and β the above system has exactly one solution. Let's denote it by $x_1{}^*$ and $x_2{}^*$. Substituting the calculated values of R&D investments into (8) and (9), we obtain the equilibrium levels of output for the leader and the follower, $q_1{}^*$ and $q_2{}^*$. From (1), we have the equilibrium price, p^*. Now, we can also calculate the equilibrium levels of profits, $\pi_1{}^*$ and $\pi_2{}^*$.

Since the algebraic solution of our model is practically hard to present due to the quadratic cost function, we will use a numerical analysis. In this paper, we consider the case of $a = 100$, $c = 1$, and $\gamma = 100$. The equilibrium results for various levels of parameter β are summarized in table 1.

Table 1. Stackelberg equilibrium for $a = 100$, $c = 1$, $\gamma = 100$, and $\beta \in [0,1]$

β	$x_1{}^*$	$x_2{}^*$	$q_1{}^*$	$q_2{}^*$	p^*	$\pi_1{}^*$	$\pi_2{}^*$
0,0	1,52056	1,29395	31,0813	23,9979	44,9208	897,32	743,24
0,1	1,41384	1,16892	31,1151	24,0378	44,8471	912,92	759,60
0,2	1,31797	1,05287	31,0998	24,0625	44,8377	925,08	773,53
0,3	1,23122	0,94354	31,0362	24,0735	44,8902	934,32	785,59
0,4	1,15244	0,83898	30,9233	24,0721	45,0046	940,95	796,22
0,5	1,08099	0,73738	30,7582	24,0589	45,1829	945,12	805,76
0,6	1,01675	0,63685	30,5360	24,0350	45,4290	946,83	814,51
0,7	0,96040	0,53508	30,2487	24,0020	45,7493	945,88	822,77
0,8	0,91386	0,42883	29,8840	23,9634	46,1526	941,77	830,92
0,9	0,88167	0,31246	29,4207	23,9278	46,6515	933,46	839,52
1,0	0,87486	0,17407	28,8178	23,9178	47,2645	918,47	849,75

Source*:* own calculations

Using table 1, we may analyze the impact of parameter β, i.e. the size of externalities in R&D, on the equilibrium decisions of firms. The R&D investments decline with the increasing scale of knowledge spillovers. The relative research spendings of the follower decline significantly faster than the investments of the leader. In the case of a research joint venture, when the parameter β equals 1, i.e., the externalities are fully internalized, the overall amount of research effort to reduce the manufacturing costs is the lowest.

For the values of parameter β greater than 0,3, an increase in the size of R&D externalities leads to a smaller supply of the final product by both firms. Each company supplies the smallest amount of the final product in the case of a joint venture, which translates into the highest market price. Thus, a research joint venture will lead to the smallest consumer surplus.

The profit of each firm is affected by the parameter β in different ways. On the one hand, the profit of the follower increases monotonically with a wider extent of research externalities, and achieves its maximum when the companies form a joint venture. On the other hand, the leader's profit initially grows when the parameter β increases, but it starts declining when this parameter exceeds 0,6. Thus, under the Stackelberg competition in the product market, a research joint venture is beneficial to the follower, but not attractive to the leader, who prefers only a medium level of technological spillovers.

3. Cartelized industry

Now, we consider the situation, in which both firms have colluded in the stage of R&D investments, as well as in the final product market. The demand function and the cost functions are assumed to be the same as in the previous section.

Again, we proceed by applying backward analysis. In the second stage of the game, the firms choose their final output levels, q_1 and q_2, for given amounts of research investments, x_1 and x_2:

$$\pi = (a - Q)Q - {q_1}^2/(c + x_1 + \beta x_2) - {q_2}^2/(c + x_2 + \beta x_1) - \gamma\frac{x_1^2}{2} - \gamma\frac{x_2^2}{2}. \tag{11}$$

At the symmetric equilibrium point, i.e. when $x_1 = x_2 = x$, the profit-maximizing output level for each company, i.e., $q = q_1 = q_2$, is obtained by solving the following first order condition with respect to q:

$$\frac{\partial \pi}{\partial q} = 0. \tag{12}$$

By solving (12), we have:

$$q = q_1 = q_2 = \frac{a(c+(1+\beta)x)}{2+4c+4(1+\beta)x}. \tag{13}$$

After substituting (13) into the inverse demand function given by (1), we obtain the equilibrium market price for the final good as a function of x:

$$p = \frac{a(1+c+(1+\beta)x)}{1+2c+2(1+\beta)x}. \tag{14}$$

In the first stage of the game, when each firm chooses the research investments, x, the companies' joint profit is given by:

$$\pi = \frac{a^2}{2}\frac{c+(1+\beta)x}{1+2c+2(1+\beta)x} - \gamma x^2. \tag{15}$$

Thus each of them will earn $\pi_1 = \pi_2 = \frac{\pi}{2}$.

To calculate the levels of R&D investments that maximize cartel profits, we solve the following first order condition with respect to x:

$$\frac{\partial \pi}{\partial x} = 0. \tag{16}$$

The obtained value of research investments undertaken by each firm in the cartelized industry, we denote by $\tilde{x}$. After substituting $\tilde{x}$ for x into (13) and (14), we find the optimal output level of each company, $\tilde{q}$, and the equilibrium market price, $\tilde{p}$, respectively.

Using (15), we calculate the joint profit of colluded firms, $\tilde{\pi}$. Thus, we can find the individual profit of company i as $\tilde{\pi}_i = \frac{\tilde{\pi}}{2}$.

Since a closed form solution of our model cannot be obtained due to the quadratic cost functions, again, we will use numerical analysis. For comparison, we consider the same set of values for our parameters, i.e., $a = 100$, $c = 1$, and $\gamma = 100$. The equilibrium results for various levels of parameter β are summarized in the table 2 below.

Table 2. Equilibrium of a cartelized industry for $a = 100$, $c = 1$, $\gamma = 100$, and $\beta \in [0,1]$

$\boldsymbol{\beta}$	$\tilde{x}$	$\tilde{q}_i$	$\tilde{p}$	$\tilde{\pi}_i$
0,0	1,00000	20,0000	60,0000	950,00
0,1	1,00917	20,2109	59,5782	959,62
0,2	1,01512	20,4013	59,1975	968,54
0,3	1,01864	20,5740	58,8520	976,82
0,4	1,02032	20,7315	58,5370	984,52
0,5	1,02057	20,8757	58,2485	991,71
0,6	1,01972	21,0084	57,9833	998,43
0,7	1,01802	21,1308	57,7384	1004,72
0,8	1,01565	21,2442	57,5116	1010,63
0,9	1,01276	21,3496	57,3009	1016,19
1,0	1,00946	21,4478	57,1044	1021,44

Source: own calculation

Based on the table 2, we can characterize the impact of the size of research externalities on the equilibrium behavior of companies. In a fully cartelized industry, the amount of the R&D investments changes nonmonotonically. The lowest levels of cost-reducing expenditures take place when there are no research externalities, or when the companies form a research joint venture ($\beta = 1$). The highest values of R&D investments are expected for the medium values of knowledge spillovers.

This result is significantly different from the case of linear manufacturing costs considered by d'Aspremont and Jacquemin, 1988, or Prokop and Karbowski, 2013. Under the assumption of the linear production costs, the research investments of cartel members grow together with the larger scale of knowledge spillovers and the largest size of investments by a cartel is expected when the firms formed a research joint venture.

In the equilibrium of a cartelized industry, a greater size of research externalities makes each firm to produce a higher amount of the final output. It leads to a price reduction, but, we should stress, that the prices are still much higher than in the noncollusive case. The profits earn by each cartel firm are monotonically growing together with an increasing size of research spillovers.

Despite the lowest cost-reducing investments made by firms in a research joint venture ($\beta = 1$), their supply of the final product is the largest, and their profits are the highest.

4. Incentives for technology improvements and industry cartelization

Now, we may use the results of the analyzes contained in table 1 and table 2 to draw final conclusions about the incentives of firms to improve the technology, and to cartelize the industry.

When the benefits of a firm from the research performed by the rival are relatively low ($\beta < 0{,}6$), the Stackelberg leader undertakes higher investments than a cartel firm Also, the follower invests more than a cartel member, but only for $\beta < 0{,}3$.

For a large scale of the R&D externalities, the cost-reducing investments made by each firm in a fully cartelized industry are significantly higher than the research expenditures made by a company in an industry characterized by the Stackelberg behavior. In the case of a research joint venture, the companies forming a cartel in the R&D stage as well as in the product market invest more in technology improvements than the noncolluding firms.[**] However, despite the more efficient manufacturing process, the cartel firms sell their final product at a much larger price than the noncolluders. Thus, it is a less convenient situation for the buyers of the final good in this industry.

No matter the size of research externalities, the profits of firms in a fully cartelized industry (the last column of table 2) is higher than the profit of the Stackelberg leader (the second to last column of table 1), or the profit of the follower (the last column of table 1). Moreover, the firms earn the highest amounts of profit when they coordinate their R&D efforts and production quantities within a cartel, and at the same time form a research joint venture in order to make a better use of knowledge exchange. As a result, we may expect that the tightening of cooperation in the R&D stage creates significant incentives for the firms to cartelize the industry. Thus, serious antitrust issues may emerge.

5. Summary and conclusions

In this paper, we analyzed the impact of companies' behavior in the final good market on their decisions in the research and development phase under the assumption of quadratic costs of manufacturing. Our model leads to the conclusion that high levels of research externalities reduce the firms' efforts to improve the production technology. The lowest values of R&D investments are expected to occur when the companies form a research joint venture.

It should be stressed that the impact of research externalities on the behavior of cartel members in the R&D stage significantly depends on the form of the cost functions. When the production costs are linear, the research investments of the cartelized industry grow together with the larger scale of knowledge spillovers, and the largest size of investment by a cartel is expected when the firms form a research joint venture.[††] However, when the manufacturing costs are quadratic, the companies that form a research joint venture in a fully cartelized industry generate the lowest levels of cost-reducing expenditures.

Comparing a research joint venture in the case of the Stackelberg competition with the case of a fully cartelized industry, we find that a bigger size of R&D spendings can be observed under the collusive behavior of firms.

The results presented in this paper are mostly based on a limited numerical analysis. In the next step, it is necessary to analyze the robustness of our conclusions to the changes of the main parameters of the model.

[**] A similar result has been obtained by d'Aspremont and Jacquemin, 1988 in the case of linear production costs.
[††] Compare Prokop and Karbowski, 2013.

Among the additional directions for future research regarding the R&D cooperation and industry cartelization, other types of competition among firms should be considered, i.e. price leadership.[‡‡] Moreover, the analysis of firms' incentives to cartelize industries as a result of cooperation in the research and development stage should be continued.

References

d'Aspremont, C. and Jacquemin, A., 1988. Cooperative and Noncooperative R&D in Duopoly with Spillovers, American Economic Review 78, pp. 1133-1137.

De Bondt, R. and Veugelers, R., 1991. Strategic Investment with Spillovers, European Journal of Political Economy 7, pp. 345-366.

Geroski, P., 1995. Do spillovers undermine the incentive to innovate? in *"Economic approaches to innovation"* S. Dowrick, Editor, Edward Elgar, Aldershot, pp. 76 – 97.

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

Prokop, J., 1999. Process of dominant-cartel formation, International Journal of Industrial Organization 17(2), pp. 241-257.

Prokop, J., 2011. Powstawanie i stabilność karteli heterogenicznych, Gospodarka Narodowa , 80/21(10), pp. 39-57.

Prokop, J. and Karbowski, A., 2013. Wpływ współpracy badawczo-rozwojowej na kartelizację gałęzi, Przegląd Zachodniopomorski, XXVIII(3), Vol. 1, pp. 259-272.

[‡‡] See, for example, the models analyzed in Prokop, 1999, and 2011.