Research Joint Venture and Open Economy

by Bum-Hoan Kim [1]

The consumer surplus under the open economy is greater than that under the closed economy from the viewpoint of social welfare. This indication has been proved when only the product market is considered. This article is to show how this result is changed if the R&D market as well as the product market is considered. We find the possibility that the closed economy is preferred to the open economy in case of the (international) R&D joint venture.

I. Introduction

This article focuses on the comparison between the open and closed economy in case that R&D activities are included. We suppose that each firm produces the homogeneous product and is engaged in the R&D activities to reduce the production (unit) cost.

For analytic convenience, this article is based on the model introduced by d'Aspremont and Jaquemin[1988]. The solution obtained by them was the result of the collusive behaviour in the R&D activities rather than cooperative R&D in the real sense, while this article adopts, in order to obtain the equilibrium of R&D joint venture, the noncooperative behaviour of firms which is the approach presented by Katz[1986].[2]

This article is organized as follows. The behavioral aspects of firms on the determination of production and R&D are introduced in the next section. Section III characterizes the equilibria in product and R&D markets and then suggests a 2-country example in which each market has only

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2) Katz[1986] examines also various benefits of the cooperative R&D of which only two are considered in this model. First, there is a benefit from "internalisation of R&D performance" which means that the firms benefit from the exchange of scientific and technological knowledges resulting from R&D conducted. Second, there is a benefit from "externalization of R&D expenditures" according to which the firms share reciprocally a part of cost of others.

one firm. Section IV concludes this research by noting the preliminary policy implications of the analysis.

II. The model

1. Behavioral analysis of firms

The game about the firms behaviors including the R&D activity consists of two stages. A firm chooses its R&D index in the first stage.[3] Given this choice of R&D, it decides the production. The game consists of 2-stage subgame perfect equilibrium. The solution of game is obtained by the backward induction method that is multi-stage decision making rule based on the perfect criterion.

We consider an economy that consists of L markets and n firms with k_l firms in the market "l".

$$(n = \sum_{l=1}^{L} k_l).$$

Given R&D in the pre-stage, the product market subequilibrium of firm i in the market l can be expressed as follows:

$$q_l^i = \arg \max_{q_l^i \in R_+} B_l^i(q_l^1, q_l^2, \cdots q_l^m),$$

where q_l^i and B_l^i are respectively the quantity and profit of firm i in the market l and "arg max" indicates an argument that maximizes the objective function. And m is the number of firms activating in the market l and m= k_l when the market is closed and m = n when the market is open.(Note that superscript indicates firm and subscript market.)

The equilibrium production can now be written by a function of only the R&D indices:

$$q_l^i = q_l^i(x^1, x^2, \cdots x^n),$$

where x^n is the R&D index of the firm n. Anticipating the product equilibrium resulting from next stage, we can write the profit and profit functions as follows :

$$q_l^i(x^1, x^2, \cdots x^n) = B_l^i(q_l^1, q_l^2, \cdots q_l^m),$$
$$\pi_l^i(x^1, x^2, \cdots x^n) = q_l^i(x^1, x^2, \cdots x^n) - D(x^i),$$

where $D(x^i)$ represents the total R&D expenditures of firm i.

The R&D subequilibrium in the closed economy (f) and in the open market (p) are respectively obtained as follows:

$$x^i(f) = \arg \max_{x^i \in R_+} \pi_l^i(x^1, x^2, \cdots x^n),$$
$$x^i(p) = \arg \max_{x^i \in R_+} \sum_{l=1}^{L} \pi_l^i(x^1, x^2, \cdots x^n).$$

2. Modelisation

The profit of firm i in the market l is;

$$B_l^i = (P_l - c^i)q_l^i, \qquad (2.1)$$

where P_l is the price in the market l and c^i is

3) Note in this article that the decision variable maximizing the objective function is not the R&D expenditures but R&D indices reflecting its performances.

the production unit cost of firm i.

We utilize the demand function and cost function introduced by d'Aspremont and Jaquemin[1988]:

$$P_l = a_l - b\sum_{i=1}^{m} q_l^i \qquad (2.2)$$

$$c^i = \alpha^i - \theta z^i \qquad (2.3)$$

$$z^i = x^i + \sum_{d \neq i}^{m} s^{d,i} x^d \qquad (2.4)$$

where a_l and b are respectively intercept and slope of inverse demand function. Also, α^i is initial cost of firm i and z^i is the accumulation of scientific and technological knowledge and θ is the technical efficiency parameter representing the efficiency of new technology w.r.t. the production unit cost.

In addition, $s^{d,i}$ is the extent to which the R&D performance of firm d is transferred to the firm i.

We suppose that $s^{d,i} = s_a$ in case that R&D is conducted individually, and that $s^{d,i} = s_a$ in case of cooperative R&D agreements. And $0 < s_a \leq 1/2 \leq s_b \leq 1$.[4)]

The firms under the product competition choose the output to maximize their profits for each market. Under the completely closed market, the firms determine R&D indices that maximize the profit of their own market. In the contrary, they choose R&D performance that maximizes the profit in other markets as well as in their own market.

Let "f" be a closed economy and "p" an open market. If we denote "b" the cooperative R&D and "a" an individual R&D, then the profit function of firm i in the market l is as follows:

$$\pi_l^i(f,a) = g_l^i - r(x^i)^2$$

$$\pi_l^i(f,b) = g_l^i - (r/n)\sum_{i=1}^{n}(x^i)^2$$

$$\pi_l^i(p,a) = \sum_{l=1}^{L} g_l^i - r(x^i)^2 \qquad (2.5)$$

$$\pi_l^i(p,b) = \sum_{l=1}^{L} g_l^i - (r/n)\sum_{i=1}^{n}(x^i)^2$$

where (1/r) is an R&D performance parameter representing the relationship between R&D expenditures and its performance. We can notice, from the above formulas, that all participating firms share R&D expenditures equally.

4) This hypothesis is restrictive and rather arbitrary. The fact that a fraction of R&D performances is $s_b > 1/2$ ($s_a < 1/2$) means a complementary(substitutive) relationship in R&D strategy. This is derived from the comparative static analysis.

III. Equilibrium in the product and R&D markets

1. Product and R&D sub-equilibria

If there is K_l firms in the l market, the product subequilibrium of firm i is as follows:

$$q_l^i(f) = [1/(K_l+1)]\,[(K_l A_l^i - \sum_{j\neq 1}^{k_l} A_l^j) + \theta(K_l z^i - \sum_{j\neq i}^{k_l} z^j)]$$

$$q_l^i(p) = [1/(n+1)]\,[(nA_l^i - \sum_{j\neq 1}^{L}\sum_{h=1}^{kj} A_l^h) + \theta(nz^i - \sum_{g\neq 1}^{k_l} z^g - \sum_{j\neq 1}^{L}\sum_{h=1}^{kj} z^h)] \qquad (3.1)$$

where $A_l^t = a_l - \alpha^t$, $t = i, j, h$.

If all the firms have an initial identical knowledge, R&D subequilibrium is, by the envelop theorem, obtained as follows:

$$\varphi(f,a) = \theta[k_l - (k_l - 1)s_a] \;/\; (k_l + 1)r$$

$$\varphi(f,b) = n\theta[k_l - (k_l - 1)sb] \;/\; (k_l + 1)r$$

$$\varphi(p,a) = \theta[n - (n - 1)s_a] \;/\; (n + 1)r \qquad (3.2)$$

$$\varphi(p,b) = n\theta[n - (n - 1)s_b] \;/\; (n + 1)r$$

where $\varphi(f,a) = \varphi(p,a) = x^i / q_l^i \varphi(f,b) = \varphi(p,b) = x^i \sum_{l=1}^{L} q_l^i$

We find now that the higher the technical efficiency and R&D performance parameters, the greater the R&D-output ratio.

If the number of firms is identical for all markets, then we have:

$$\varphi(f,a) \le \varphi(p,a) < \varphi(p,b) \le \varphi(f,b) \qquad (3.3)$$

where the equality is satisfied if $s_a = s_b = 1/2$.

We find the following results from (3.3):

First, the firm has a higher R&D-output ratio under the open market than that under the closed market when R&D activities are conducted individually. In other words, it is willing to increase the R&D expenditures in order to improve market competitiveness when there is no cooperation in R&D activities. Second, each firm benefits more from the cooperative R&D agreements than from individual R&D activities regardless of whether the market is open or closed. It means that R&D incentives resulting from reciprocal allocations of R&D expenditures are greater than R&D disincentives due to common shares of R&D performance.[5] In the last, the R&D incentive to production is greater under the closed market than under the open market when the cooperative R&D agreements is carried out. This reason is: the sharing of R&D performances does not affect the R&D incentives in the closed economy, while it causes the weakness of market competitiveness in the open market.

From the formulas (3.1) and (3.2), the equilibria in product and R&D market can be obtained. In the next section, we consider 2-country model in which there is only one firm in each country (i.e. $L = 2$, $k_l = 1$, $\forall l=1,2$).

2. Case of two countries

Tying (3.1) and (3.2) together, we have the equilibria of R&D and production for the firm of each country. Let X and Q be the total R&D performance and production of two countries respectively: [6]

$$X(f,a) < X(p,a) < X(p,b) \le X(f,b) \quad \text{if } s_b \ge 7/8, \qquad (3.4)$$

$$X(f,a) < X(p,a) < X(f,b) < X(p,b) \quad \text{otherwise.}$$

5) This comes from the fact that the R&D incentive of firms participating in the cooperative R&D is negatively related with the internalisation of R&D performance but positively with externalisation of R&D expenditures.

6) The equilibria obtained consider the second condition ($C_x < 0$) and stability condition($S_x > 0$) of profit maximization. This article utilizes the conditions defined by the followings:

$$C_x = \pi^i, \; i = 1, 2.$$

where $\pi_{ii}^i(\pi_{ij}^i, j \ne 1)$ is the second direct and cross differentiation.

where the equality is satisfied if $s_b = 7/8$.

$$Q(f,a) < Q(p,a) < Q(p,b) \le Q(f,b),$$

if $s_b > 7/8$ and

$$(4/9)(2 - s_b)(1 + s_b) < (br/\theta^2) \le (2/3)(2s_b - 1)(1 + s_b) \quad (3.5)$$

$$Q(f,a) < Q(p,a) < Q(f,b) < Q(p,b), \text{ otherwise.}$$

where equality is satisfied if $s_b = 7/8$. We have (br/θ^2) = $(2/3)(2s_b - 1)(1 + s_b)$ where br/θ^2 indicates the extent to which the production is affected by R&D expenditures. Note that the inequality of left side of (3.5) is the condition of stability.

$$X(f) = \sum_{l=1}^{2} x_l^1$$

$$X(p) = \sum_{i=1}^{2} \sum_{l=1}^{2} x_l^i$$

$$Q(f) = \sum_{l=1}^{2} q_l^1$$

$$Q(p) = \sum_{i=1}^{2} \sum_{l=1}^{2} q_l^i$$

From (3.5), we find that more production results from the closed economy than from the open economy, both if the industry is technology-efficient and if the cooperative R&D agreements with perfect(or quasi-perfect) sharing of R&D performances between firms are in effect.[7] This implies: there is a possibility, in a high-technology industry, that R&D disincentives due to the competitive weakness resulting from market opening dominate those due only to any one market in the closed economy. In addition, It is not difficult to find the condition that the firm with a lower technology can survive in case of cooperative R&D agreements.[8]

7) In the contrary, there is more R&D incentive in the closed economy than in the open economy, only if there are the cooperative R&D agreements with perfect sharing of R&D performances between firms.

IV. Conclusion

We show in this article that the unconditional market opening is not the best solution. In other words, the closed market is preferred to the open market in case of well-coordinated cooperative R&D agreements, especially in high R&D-intensity industry. However, the world now have a move to market opening. The implication of our study could be best summarized as follows: it is preferable, from the viewpoint of consumer surplus, that the more-advanced-technology country must, at the expense of market opening, seek positively for the R&D cooperation with less-advanced-technology country rather than conduct R&D activities individually.

8) The domain of positive production is as follows:

$$(\pi_{11}^1 + 2\pi_{12}^1) / (\pi_{21}^2 + 2\pi_{22}^2) < (A_1^2 + A_2^2) / (A_1^1 + A_2^1) < 1$$

If we let be

$$T = (\pi_{11}^1 + 2\pi_{12}^1) / (\pi_{21}^2 + 2\pi_{22}^2)$$

we have: $0 < T(p,b) < T(p,a) \; (< 1)$.

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Bum-Hoan Kim re-ceived the M.A. degree in Economics from Korea University in 1983, and Ph.D. degree in Economic Science from the University of Toulouse in 1992. Since 1983, he has performed R&D policy principally in telecommunications sector, in ETRI.