Investment strategy for a multinational enterprise: R&D investment and foreign direct investment*

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Abstract

This paper analyzes how the investment strategies chosen by a multinational enterprise inter-relate each other when it is constrained to budged in investing inward and outward in an oligopolistic market. I assume that if a multinational enterprise increases in inward cost-reducing R&D investment, then the residual resource necessary for outward foreign direct investment will be reduced. It is shown that whether firms' R&D investments are strategic substitutes or strategic complements are endogenously determined depending on how much a multinational invests in R&D. The way how the initial technology gap between a multinational and firms of the host country is affected by the host country's trade policy is also considered.

1. Introduction

Nowadays, the activities of firms are interrelated each other across national borders and even a local small and medium-sized enterprise has to recognize the world market. Multinational enterprises (henceforth, MNEs), which are defined as firms engage in foreign trade and foreign direct investment, are no longer a special class of firms' organization.[1] To survive internationally competitive markets, MNE must maintain competitiveness and investment in innovative activities.

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1 The United Nations defines MNE as firms owning a production facility and a business institution in more than 2 countries.

In the early 60's when the Japanese market was just opened to the foreign affiliates, the investment strategies for foreign investors were limited. For IBM, then the giant in the world computer industry, it was no exception. IBM was first allowed to export computers to Japan, but barriers for foreign direct investment (henceforth, FDI) were still very high and it took some time until its fully owned subsidiary was opened. When a firm behaves as MNE, it confronts with investment strategies how much to invest inward in product and process innovation, i.e., R&D investment, and outward in obtaining part of or entire ownership of a foreign subsidiary, i.e., FDI, or in forming business alliance with a local partner if necessarily. It is a MNE's decision-making problem on resource allocation when its budget is constrained.

There are many literature on firms' R&D investment competition in oligopolistic markets, in which technological spillovers play central role in deciding the level of firm's R&D investment. For example, d'Aspremont and Jacquemin (1988), Suzumura (1992) and Kamien et al. (1992), have analyzed the conditions under which collaborative R&D investments improve social welfare. But these literature do not consider the possibility of firms' foreign operations. On the other hand, most of literature on strategic trade policy deal with market structures as given and trade theorists conventionally do not consider how inward and outward investment policies of MNE inter-relate each other when they face competition both in production and innovation.[2] With very few exception like Horstmann and Markusen (1987), Wong (1995) and Petit and Sanna-Randaccio (2000), innovative activities and firms' strategies for international expansion have generally been dealt with as separate issues. Horstmann and Markusen (1987) construct a model which allowed the existence or non-existence of MNE to arise as an equilibrium phenomenon. They show that it is the market size that affects MNE's expansion strategies between export and FDI, and MNE tends to choose FDI if firm-specific and export costs are large relative to plant scale economies. Extending them, Wong (1995) internalizes MNE's strategic choice between export and FDI in a duopoly model. Wong (1995) assumes that MNE is constrained to budget and shows how the money is allocated between inward and outward investments. However, competitiveness effect enhanced by the increase in R&D investment is not considered and interaction between MNE's investment strategies and those of firms in the host country are absent in the models mentioned above.

The objective of this paper is to make clear how the inward and outward investment strategies of MNE inter-relate each other when the money spent for the investments is limited and goods are supplied in an imperfectly competitive market. I construct the model by assuming that if MNE increases in R&D investment, which contributes to reduce production marginal cost, the money left for setting up a subsidiary is reduced, which results in the increase in its operational cost. If the options for foreign expansion of MNE are export and/or FDI, and

2 Markusen (2002) provides comprehensive theoretical framework to understand MNE in economics.

MNE initially has superior production technology than firms in the host country, it was shown that: (i) whether R&D investments are strategic substitutes or strategic complements is determined depending on the magnitude of MNE's R&D investment.[3] If it is very small (big), firms consider R&D investments be strategic substitutes (complements). (ii) If R&D investments are strategic substitutes, protective trade policy by the host government reduces technology gap between MNE and firms in the host country. The same effect can be obtained if the home government tries to promote inward FDI by preparing infrastructure and/or reducing non-trade barrier, when R&D investments are strategic complements.

The paper is organized as follows. Section 2 explains the framework of the model reflecting inter-relation between inward and outward investment strategies for MNE. Section 3 derives the characteristics of the equilibrium. The effects on the market brought by trade policy of the host country are statically analyzed. Section 4 concludes.

2. The model

I consider a model with two countries, a foreign country and a home country, and one MNE locates in the foreign country and n firms in the home country. All firms produce homogeneous goods. There is no uncertainty in the market as well as in firms' investments. MNE (I simply call the head office of a multinational enterprise MNE, henceforth) must decide investment and production strategies. To focus on the issues of MNE's decision-making problems, I follow Wong (1995) and assume that MNE may export but home firms can not.[4] So, MNE monopolizes foreign market, however, the home country is under oligopolistic competition.

Firms invest in cost-reducing R&D activities, that is, process innovation is undertaken. The possible instruments for MNE's foreign operation are assumed export and/or FDI.[5] MNE may set up a foreign subsidiary by evading knowledge spillover to the local competitors. With characteristics of quasi-public goods, I assume that R&D activities are conducted only in the head office. So the subsidiary can use the same production technology to that of the parent company without cost. When MNE exports, it must pay specific type of export cost including tariff and shipping costs. In case for FDI, initial investment money is required and additionally,

3 For simplicity, I assume that FDI is the only option for outward investment other than export, and that MNE can not raise fund. Or otherwise, it may be acceptable if we restrict our attention on firms' short-run activities.

4 This will be the case when the initial production technology, which is expressed in production marginal cost, of MNE is superior to that of the home firm. As I explain later, of course, firms can improve production efficiency by investing into R&D activities which contribute to reduce production marginal cost.

5 Agency problem in FDI is assumed away since there is no asymmetric information. The case for MNE's business alliance with a local firm will be considered in the next version of this paper.

operational or distribution costs for localization is also necessarily. I assume that the bigger the amount of initial investment for FDI, the easier the subsidiary sells its goods in the host country since its distribution cost will be reduced.[6]

Let $Y^*=y^*$ and $Y=\sum y_j$, $j=1, 2,..., N, E, F$, be the market demand for the foreign and home countries, respectively, where E and F mean respectively exports by MNE and goods produced by MNE's subsidiary. The asterisks attached to the variables mean foreign market. Assume that inverse demand in two markets are linear:

(A-1) $p^*=a^*-b^*y^*$ and $p=a-bY$,

where p^* and p are prices and $a^*, b^*, a, b>0$.

Before R&D investments, firms' constant production marginal costs are assumed:

(A-2) $c_i>c^*>0$, $i=1, 2,..., N$.

With R&D efforts, firms can reduce production marginal cost, because there is no uncertainty in R&D investment. Let e^* and e_i be respective MNE's and home firm's R&D efforts, and production functions of firm's R&D effort are assumed $x^*=f^*(e^*)$ and $x_i=f_i(e_i)$, where x^* and x_i are firm's R&D outputs. Like most of effort consuming activities, R&D activities exhibit decreasing return to scale so that quadratic R&D expenditure of MNE and home firms with unit effort cost can be $\frac{x^{*2}}{2}$ and $\frac{x_i^2}{2}$, respectively.[7]

Since each home firm has no investment option other than R&D investment, it is free from allocation problems so that $x>0$. Profit of the home firm is

(1) $\pi_i=[a-by_i-b\sum y_j]y_i-(c_i-x_i)y_i-k_{iR}$,

where $k_{iR}=\frac{x_i^2}{2}$ and $i=1,2,..., N, j=1,..., N, E, F, i\neq j$.

In contrast to home firms, MNE is constrained to the budget. Let MNE's limited amount of fund is $K^*>0$, which will be allocated among possible two types of investments: inward R&D investment and outward FDI. MNE's R&D investment K_R is $K_R=\frac{x^{*2}}{2}\geq 0$, i.e., $x^*\geq 0$, and its initial investment for FDI is $K_F\geq 0$, the sunk cost. For simplicity, I assume that R&D activities are conducted only in the parent company. So, when budget constraint for MNE holds equal, it becomes

6 It is said that one of the main reasons for the success of P&G in the oligopolistic Japanese consumer goods market is in its huge investment in advertisement, which has established its brand-image so as to contribute to reduce its actual distribution cost.

7 The assumption of diminishing returns to R&D expenditure is typical in strategic R&D investment literature. (See, for example, d'Aspremont and Jacquemin (1988) and Suzumura (1992).) For its justification, d'Aspremont and Jacquemin (1988) cited from Dasgupta (1986, p. 523) that "the technological possibilities linking R&D inputs and innovative outputs do not display any economies of scale with respect to the size of the firm in which R&D is undertaken".

(A-3) $K^*=K_R+K_F$,

so that K_F can be rewritten as

(A-4) $$K_F = K^* - K_R = K^* - \frac{x^{*2}}{2} \geq 0,$$

where $\frac{\partial^2 K_F(x^*)}{\partial x^{*2}} \leq 0$ according as $\frac{\partial K_F(x^*)}{\partial x^*} = -x^* \leq 0$. The more MNE spends in R&D, the less the fund is left for FDI. On the other hand, there are counter effects on subsidiary's market competitiveness when MNE increases R&D investment: directly it reduces production marginal cost and indirectly increases its distribution cost. To make clear this process caused by allocation issue, I define distribution cost as following. Let d per unit distribution cost for the subsidiary, distribution cost function can be defined as

(A-5) $d=d(K_F)$, $d'<0$, $d''>0$, $d(0)=\infty$, $d(K^*) = \underline{d} > 0$,

where $d' = \frac{\partial d(K_F)}{\partial K_F} < 0$ is direct distribution-cost-reduction-effect brought by the increase in the amount of initial investment, and $d'' = \frac{\partial^2 d(K_F)}{\partial K_F{}^2} > 0$.[8] The lowest positive distribution cost, $d(K^*) = \underline{d} > 0$, is realized if entire money is invested in FDI, or MNE does not invest in R&D. As seen in (A-4), it is noted that there is an indirect distribution-cost-increase-effect, because K_F is a function of R&D investment. It can be checked by substitution (A-4) for (A-5) that the change in R&D effort is

(A-6) $$\frac{d(K_F)}{dx^*} = \frac{\partial d(K_F)}{\partial K_F}\frac{dK_F(x^*)}{dx^*} = -x^* d' \geq 0,$$

$$\frac{d^2 d(K_F(x^*))}{dx^{*2}} = -d' + (x^*)^2 d'' > 0 \quad \text{if} \quad x^*>0.$$

The more MNE increases in R&D investment, which reduces the money left for FDI, the higher distribution cost of the subsidiary becomes. With these assumptions, variable cost C_F for the subsidiary can be

(A-7) $C_F=[c^*-x^*+d(K_F)]y_F$,

where $\frac{dC_F(x^*, K_F(x^*))}{dx^*} = \frac{dC_F}{dx^*} + \frac{\partial C_F}{\partial K_F}\frac{dK_F(x^*)}{dx^*} = -(1 + x^* d')$ is the marginal effect on C_F when R&D investment is changed.

I assume that subsidiary considers its own profit only. This means that it does not matter how its production strategy affects exports, the products of its parent company. This may be the case when MNE expects subsidiary to monitor production efficiency of the group. Because, rivalry or tension between exports and subsidiary's produciton may reduce X-inefficiency. Then, joint profit of MNE, which is earned through possible three channels, i.e., foreign monopoly market, exports and FDI, is defined as

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8 Trivially, there is no FDI when all money is invested in R&D investment so that distribution cost becomes infinity. Since $K_F=0$ and $K^*=K^*_R$ (or $x^* = \sqrt{2K^*}$), then $y_F=0$. (See Fig.1.)

(2) $\pi^M = \pi^* + \pi_F$

$= [p^* y^* - (c^* - x^*) y^* - K_R + (a - bY) y_E - (c^* - x^* + t) y_E]$

$+ [(a - bY) y_F - (c^* - x^* + d(K_F)) y_F - K_F],$

where $t>0$ is the given level of per unit export cost. Superscript M attached to variables means MNE.

3. MNE's decisions: Export and/or FDI under process innovation

3.1 Firms' decisions

I set a simple two-stage game:

(i) t=1; at the beginning of the first stage, given trade policies of the home country, home firms and MNE decide the level of R&D investments. MNE, however, has to decide its mode for foreign expansion, i.e., export and/or FDI, at the same time. Since there is no uncertainty in R&D investment, effort outcomes become clear at the end of this stage, and

(ii) t=2; in the second stage, using new production technology firms produce goods and engage in a Cournot-Nash competition.

As convention, the model is solved backward. The solution concept is sub-game perfect Nash equilibrium (SPNE) and all equilibria are assumed to be interior and stable.

First, I solve for the equilibrium of the oligopoly market in the host country for the second stage. Representative home firm i maximizes its profit (1) in terms of y_i, and its first-order condition becomes

(3) $a - 2by_i - b(\sum y_j) = c_i - x_i$, $\quad i=1,2,\ldots, N, \quad j=1,\ldots, N, E, F, \quad i \neq j.$

On the other hand, since MNE does not control production strategy of the subsidiary, they decide production independently. MNE maximizes joint profit (2) in terms of y^* and y_E, and the subsidiary in y_F. First-order conditions for the group are

(4) $a^* - 2b^* y^* = c^* - x^*.$

(5) $a - 2by_E - b(\sum y_l) = c^* - x^* + t \quad l=1,2,\ldots, N, F,$

(6) $a - 2by_F - b(\sum y_m) = c^* - x^* + d(K_F) \quad m=1,2,\ldots, N, E,$

The equilibrium output, price and profit in the foreign market are derived by solving (4):

(4′) $Y^* = y^* = (a^* - c^* + x^*)/(2b^*), \quad p^* = (a^* + c^* - x^*)/2, \quad \pi^* = (a^* - c^* + x^*)^2/(4b^*).$[9]

Before deriving the equilibrium values for the home market, define reaction functions of

9 Second-order conditions of home firms and MNE are satisfied. (See Appendix 1.)

firms in the home market as

(A-8) $\quad \varphi_j(Y_{-j}) \equiv \text{aug max}_{(y_j \geq 0)} \pi_j(y_j, Y_{-j})$,

where $Y_{-j}=\sum_{j\in(1,\ldots,j-1,j+1,,,N,E,F)} y_j$, $j=1,\ldots$, N, E, F. From (3), (5), (6), we have $\partial\varphi_j/\partial Y_{-j}<0$, and this means that firm's individual reaction curve slopes downward, that is, goods are strategic substitutes.[10]

To derive market equilibirum, we rewrite firms' first-order conditions (3)-(5) as

(3') $\quad a-by_i-bY=c_i-x_i$

(5') $\quad a-by_E-bY=c^*-x^*+t$

(6') $\quad a-by_F-bY=c^*-x^*+d(K_F)$.

By summing up (3'), (5'), (6)', we have

(7) $\quad a(N+2)-b(N+3)Y=\sum_j^N(c_i-x_i)+2(c^*-x^*)+t+d(K_F)$,

and then we obtain following equilibrium total output and price,

(8)
$$Y=\frac{a(N+2)}{b(N+3)}-\frac{\sum_i^N(c_i-x_i)+2(c^*-x^*)+t+d(K_F)}{b(N+3)}$$
$$p=\frac{a}{(N+3)}+\frac{\sum_i^N(c_i-x_i)+2(c^*-x^*)+t+d(K_F)}{(N+3)}.$$

Substitution (8) for (3'), (5'), (6)' yields firm's equilibrium output in the home market:

(9)
$$y_i=\frac{a-(N+2)(c_i-x_i)+\sum_{j,i\neq j}^N(c_j-x_j)+2(c^*-x^*)+t+d(K_F)}{b(N+3)}$$
$$y_E=\frac{a+\sum_i^N(c_i-x_i)-(N+1)(c^*-x^*)-(N+2)t+d(K_F)}{b(N+3)}$$
$$y_F=\frac{a+\sum_i^N(c_i-x_i)-(N+1)(c^*-x^*)+t-(N+2)d(K_F)}{b(N+3)}.$$

From (8) and (9), we know that the equilibrium industry's and firm's outputs depend on the sum of marginal costs in the home country, which is affected by firm's R&D investment, MNE's expansion mode, and the number of domestic firms. These results are contrary to those obtained when marginal costs are constant, that is, R&D investment is assumed away. (See, Shy (1995), Proposition 6.6.)

By assessing those equilibrium values, we have

(10)
$$y_i \gtreqless y_E \quad \text{if} \quad c_i-x_i \lesseqgtr c^*+t-x^*,$$
$$y_i \gtreqless y_F \quad \text{if} \quad c_i-x_i \lesseqgtr c^*+d(K_F)-x^*,$$
$$y_E \gtreqless y_F \quad \text{if} \quad t \lesseqgtr d(K_F),$$

when domestic firms are assumed symmetry.[11] After R&D investments, if home firm's marginal cost is still higher than MNE's, market share of home firm is smaller than exports and that of subsidiary. But note that marginal change in R&D investment of MNE affects subsidiary's

10 For firm's strategic behavior regarding to its choice variable, see Bulow, et. al (1985).

11 $y_i-y_E=[(c^*-x^*+t)-(c_i-x_i)]/b$, $y_i-y_F=[(c^*-x^*+d(K_F))-(c_i-x_i)]/b$, and $y_E-y_F=(d(K_F)-t)/b$.

variable cost so that subsidiary's market share will be affected.[12] The difference in exports and subsidiary's outputs depends on the difference in export cost and distribution cost, where marginal increase in R&D investment of MNE reduces subsidiary's share relative to exports. Whether MNE exports or not, however, depends on the magnitude of relative export cost to distribution cost. If export cost is as high as $t>d(K_F)$, then y_E=0 and y_F>0, that is, FDI is chosen for so-called tariff evasive strategy. Even if MNE holds export, (i) buffer-effect; it owns a subsidiary and earns monopoly rent in the foreign market, (ii) resource-allocation-effect; since ex-ante production technology is superior to those of home firms, MNE can put bigger weight on FDI and allocate more money for FDI, which reduces subsidiary's distribution cost.

Lemma 1. Since MNE's resource allocation between R&D investment and FDI directly affects its production marginal cost and indirectly operational costs of the subsidiary, MNE's strategy affects the market equilibrium by changing distribution of firm's marginal cost in the home country.

From (8) and (9), we have

$$\frac{\partial Y}{\partial x_i}=\frac{1}{b(N+3)}>0,\quad \frac{\partial p}{\partial x_i}=-\frac{1}{N+3}<0,$$

$$\frac{\partial y_i}{\partial x_i}=\frac{(N+2)}{b(N+3)}>0,\quad \frac{\partial y_i}{\partial x_j}=\frac{\partial y_j}{\partial x_i}=-\frac{1}{b(N+3)}<0,\quad \frac{\partial y_E}{\partial x_i}=\frac{\partial y_F}{\partial x_i}=-\frac{1}{b(N+3)}<0,$$

$$\text{(11)}\qquad \frac{\partial Y}{\partial x^*}=\frac{2+x^*d'}{b(N+3)},\quad \frac{\partial p}{\partial x^*}=\frac{-(2+x^*d')}{N+3},$$

$$\frac{\partial y_i}{\partial x^*}=\frac{-(2+x^*d')}{b(N+3)},\quad \frac{\partial y_E}{\partial x^*}=\frac{(N+1)-x^*d'}{b(N+3)}>0,\quad \frac{\partial y_F}{\partial x^*}=\frac{(N+1)+(N+2)x^*d'}{b(N+3)},$$

$$\frac{\partial(y_E+y_F)}{\partial x^*}=\frac{(N+1)(2+x^*d')}{b(N+3)},\quad \frac{\partial(y_E-y_F)}{\partial x^*}=-\frac{x^*d'}{b}>0,$$

where

$$\text{(12)}\qquad \frac{\partial y_i}{\partial x^*}\gtreqless 0,\quad \frac{\partial Y}{\partial x^*}\lesseqgtr 0,\quad \frac{\partial p}{\partial x^*}\gtreqless 0\quad \text{according as}\quad 0\lesseqgtr 2+x^*d'$$

$$\frac{\partial y_F}{\partial x^*}\geq 0\quad \text{if}\ \ 0\geq x^*d'\geq -\frac{2}{3},$$

$$\frac{\partial y_F}{\partial x^*}\ ?\quad \text{if}\ \ -\frac{2}{3}>x^*d'>-1,$$

$$\frac{\partial y_F}{\partial x^*}<0\quad \text{if}\ \ -1\geq x^*d'.$$

The change in home firm's R&D investment affects positively on its own market outputs, and negatively on its domestic rival's and subsidiary's output as well as export.[13] Due to competitiveness effect, increase in MNE's R&D investment promotes exports, however, its impact on the outputs of the subsidiary and the market are ambiguous depending on the sign of

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12 See $dC_F/dx^*=-(1+d'x^*)$ in (A-7).

13 For derivation of (11) and (12), see Appendix2.

(2+x^*d') and the number of entrants. The difference in export and the subsidiary's output increases with MNE's R&D investment, market share of them are ambiguous; $\partial(y_E - y_F)/\partial x^* > 0$ and $\mathrm{sig}\,\partial(y_E + y_F)/\partial x^* = \mathrm{sig}(2 + x^*d')$. If MNE increases R&D investment, its production marginal cost decreases and distribution cost of subsidiary increases. These opposite effects affect the subsidiary's output. In the lower range of R&D expenditure, $0 \geq x^*d' \geq -(2/3)$, the former effect exceeds the latter and output of the subsidiary increases; $\partial y_F/\partial x^* \geq 0$. In the range of $-(2/3) > x^*d' > -1$, the sign of $\partial y_F/\partial x^*$ is ambiguous. However, in the relatively higher range of R&D expenditure, $-1 \geq x^*d'$, marginal increase in R&D investment pushes up distribution cost higher and offsets the increase in production competitiveness. This results in the reduction of subsidiary's output; $\partial y_F/\partial x^* < 0$.[14] These are summarized as following:

Lemma 2. If MNE increases R&D investment, its export and the difference in export and subsidiary's output increases. However, the effects on subsidiary's output, individual home firm's output as well as total outputs of the home country are ambiguous. In the lower range of R&D expenditure, MNE can increase both export and subsidiary's output by increasing R&D expenditure.

Next, solve for firms' optimal investments in the first-stage. Given the equilibrium outputs in the second-stage, $y^*(x^*)$, $y_i(x_i, x_j, x^*; \mathrm{N}, t, \mathrm{K}^*)$, $y_F(x_i, x^*; \mathrm{N}, t, \mathrm{K}^*)$, $y_E(x_i, x^*; \mathrm{N}, t, \mathrm{K}^*)$, home firms maximize profits and MNE joint profit in terms of own R&D investment.

The first-order condition of the home firm i becomes

(13) $$\pi^i_{x_i} = (p'\frac{\partial Y_{-i}}{\partial x_i} + 1)y_i - x_i = 0,$$

where $\pi^i_{x_i} = \frac{\partial \pi^i}{\partial x_i}$ *and* $\frac{\partial Y_{-i}}{\partial x_i} = \sum_{j,i\neq j}^{N} \frac{\partial y_j}{\partial x_i} + \frac{\partial y_E}{\partial x_i} + \frac{\partial y_F}{\partial x_i}$. Assessing this with (11), home firm's reaction in the R&D investment-plane is

(14) $$\frac{2(N+2)}{(N+3)}y_i - x_i = 0.$$ [15]

On the other hand, objective function of MNE becomes

(15) $$\pi^M = [p^* - (c^* - x^*)]y^* + [p - (c^* - x^*)](y_E + y_F) - ty_E - d(K_F(x^*))y_F - K^*,$$

which is maximized in terms of x^*. Its first-order condition is

(16) $$\pi^M_{x^*} = y^* + y_E(p'\frac{\partial Y_{-E}}{\partial x^*} + 1) + y_F(p'\frac{\partial Y_{-F}}{\partial x^*} + 1 + x^*d') \leq 0,$$

where $\pi^M_{x^*} = \frac{\partial \pi^M}{\partial x^*}$, $\frac{\partial Y_{-E}}{\partial x^*} = \sum_i^N \frac{\partial y_i}{\partial x^*} + \frac{\partial y_F}{\partial x^*}$ *and* $\frac{\partial Y_{-F}}{\partial x^*} = \sum_i^N \frac{\partial y_i}{\partial x^*} + \frac{\partial y_E}{\partial x^*}$. Assessing this with (11) and with symmetry assumption of the home firms, MNE's reaction in R&D investment-plane is

(17) $$y^* + \frac{2}{(N+3)}\{y_E[(N+1) - x^*d'] + y_F[(N+1) + (N+2)x^*d']\} \leq 0.$$

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14 See Fig.1 and 2.

15 (14) and following (17),(20),(23) are derived in Appendix 3 and 4.

By solving N+1 simultaneous equations of (14) and (17), we have equilibrium R&D investments level as

(18) $\tilde{x}_i = x_i(N,t,K^*)$ and $\tilde{x}^* = x^*(N,t,K^*)$,

where ~ attached to the variables mean equilibrium values. The other SPNE outcomes are derived by substitution of (18) for (8) and (9). Since the set $(\tilde{x}_i, \tilde{x}^*)$ satisfies (14) and (17), output of home firm is $\tilde{y}_i > 0$ as far as $\tilde{x}_i > 0$. However, if $\tilde{x}^*=0$, then (17) becomes $\tilde{y}^* + \frac{2(N+1)}{(N+3)}(\tilde{y}_E + \tilde{y}_F) > 0$, which contradicts. That is, the optimal R&D investment of MNE is positive: $\tilde{x}^* > 0$.

Lemma 3. The optimal R&D investment is positive for MNE. At the equilibrium, R&D investment of producing firm depends on the number of domestic firms, export cost and MNE's available fund.

3.2 Comparative statistics

To see how the change in rival firm's R&D investment and MNE's export cost affect firm's decision, I perform comparative static analysis under the assumption of symmetric domestic firms. Total differentiation of (13) yields

(19) $\pi^i_{x_i x_i} dx_i + \sum_{j,j\neq i}^{N} \pi^i_{x_i xj} dx_j + \pi^i_{x_i x^*} dx^* + \pi^i_{x_i N} dN + \pi^i_{x_i t} dt + \pi^i_{x_i K^*} dK^* = 0$,

where subscripts attached to $\pi^i_{x_i}$ denote cross-derivatives.[16] Then from (11), we have

(20)
$$\pi^i_{x_i x_i} = \frac{2(N+2)^2 - b(N+3)^2}{b(N+3)^2} < 0,$$
$$\pi^i_{x_i xj} = -\frac{2(N+2)}{b(N+3)^2} < 0,$$
$$\pi^i_{x_i x^*} = -\frac{2(N+2)(2+x^*d')}{b(N+3)^2} \gtreqless 0 \quad \text{according as} \quad 0 \lesseqgtr 2+x^*d',$$
$$\pi^i_{x_i t} = \frac{2(N+2)}{b(N+3)^2} > 0,$$
$$\pi^i_{x_i K^*} = \frac{2(N+2)d'}{b(N+3)^2} < 0.$$

For home firm, whether R&D investment of MNE is strategic substitutes or complements depends on the sign of $(2+x^*d')$. Fig.2 shows the relation between R&D investment of MNE and $(2+x^*d')$, when [$K^*=10$, $d = 1/\sqrt{K_F(x^*)}$]. MNE's R&D investment affects competitiveness of its export and subsidiary's, which in turn affects home firm. If it places bigger weight on FDI as in the range of $(2+x^*d')>0$, then R&D investments are strategic substitutes. With smaller weight like $(2+x^*d')<0$, strategic complements. With (20) and assuming $b > \frac{2(N+2)^2}{(N+3)^2}$, which is sufficient condition for home firm's second-order condition in the first stage, we have

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16 We have to analyze how the change in the number of entrants affects the market. I deal with this issue in the next version of this paper, which will analyze the possibility of business alliance.

$$(21)\qquad \frac{dx_i}{dx_j} = -\frac{\pi^i_{x_i x_j}}{\pi^i_{x_i x_i}} < 0, \qquad sign\frac{dx_i}{dx^*} = -\frac{\pi^i_{x_i x^*}}{\pi^i_{x_i x_i}} \Leftrightarrow sign\,\pi^i_{x_i x^*}$$

For MNE, total differentiation of (16) yields

$$(22)\qquad \pi^M_{x^*x^*}dx^* + \sum_i^N \pi^M_{x^*x_i}dx_i + \pi^M_{x^*N}dN + \pi^M_{x^*t}dt + \pi^M_{x^*K^*}dK^* = 0\,.$$

Then from (11), we have

$$(23)\qquad \pi^M_{x^*x^*} = \frac{1}{2b^*} + \frac{2\{[(N+1)-x^*d']^2 + [(N+1)+(N+2)x^*d']^2\}}{b(N+3)^2} - \frac{G\{2y_E + y_F[b(N+3)-(N+1)]\}}{N+3} < 0,$$

$$\pi^M_{x^*x_i} = -\frac{2(N+1)(2+x^*d')}{b(N+3)^2} \gtreqless 0 \quad \text{according as} \quad 0 \lesseqgtr 2+x^*d',$$

$$\pi^M_{x^*t} = \frac{2}{b(N+3)^2}[-(N+1)^2 + 2(N+2)x^*d'] < 0,$$

$$\pi^M_{x^*K^*} = -\frac{2d'\{(N+1)^2 + [1+(N+2)^2]x^*d'\}}{b(N+3)^2} - \frac{2x^*d''}{N+3}(y_E - y_F),$$

where $G=d'-(x^*)^2d''<0$. MNE's second-order condition in the first stage is satisfied if and only if $y_F>0$, i.e., $K_F>0$, and $b<\frac{N+1}{N+3}$.[17] Since optimal R&D investment is strictly positive for MNE (Lemma 3), MNE invests in both R&D and FDI. For MNE, too, whether R&D investments of home firms are strategic substitutes or complements depends on the sign of $(2+x^*d')$, the distribution-cost-reducing-effect. If it places bigger weight on FDI, then R&D investment is strategic substitutes. With smaller weight, strategic complements. With $\pi^M_{x^*x^*}<0$ and (22), we have

$$(24)\qquad sign\frac{dx^*}{dx} = -\frac{\pi^M_{x^*x}}{\pi^M_{x^*x^*}} \Leftrightarrow sign\,\pi^M_{x^*x}\,.$$

Proposition1. The investment policy of MNE determines whether R&D investments are strategic substitutes or complements. In particular, they are strategic substitutes (complements) with sufficiently large (small) spending in FDI. The joint investments in R&D and FDI are optimal for MEN. Moreover, MNE invests in both R&D and FDI in the equilibrium.

Next, look into how the changes in parameters like home country's trade policy and the amount of MNE's initial fund affect the market. If we assume the equilibrium is stable under $\Delta = \pi^i_{x_i x_i}\pi^M_{x^*x^*} - \pi^i_{x_i x^*}\pi^M_{x^*x_i} > 0$, we have

$$(25)\qquad \begin{bmatrix} \pi^i_{x_i x_i} & \pi^i_{x_i x^*} \\ \pi^M_{x^*x_i} & \pi^M_{x^*x^*} \end{bmatrix} \begin{bmatrix} dx_i \\ dx^* \end{bmatrix} = -\begin{bmatrix} \pi^i_{x_i t} \\ \pi^M_{x^*t} \end{bmatrix} dt - \begin{bmatrix} \pi^i_{x_i K^*} \\ \pi^M_{x^*K^*} \end{bmatrix} dK^*,$$

17 This means $\sqrt{2K^*} > \tilde{x}^* > 0$.

and

$$\text{(26)}\qquad \begin{aligned} \frac{dx_i}{dt} &= \frac{-\pi^i_{x_i t}\pi^M_{x^*x^*} + \pi^i_{x_i x^*}\pi^M_{x^*t}}{\Delta} > (?)0 \quad \text{if} \quad \pi^i_{x_i x^*} \le (>)0, \\ \frac{dx^*}{dt} &= \frac{-\pi^i_{x_i x_i}\pi^M_{x^*t} + \pi^i_{x_i t}\pi^M_{x^*x_i}}{\Delta} < (?)0 \quad \text{if} \quad \pi^M_{x^*x_i} \le (>)0, \end{aligned}$$

from (19) and (22), where $dN=0$ and $dx_j=0$, $j=1,\ldots,N$, $i \neq j$, is presumed. In case that R&D investments are strategic substitutes, i.e., $\pi^i_{x_i x^*} < 0$ and $\pi^M_{x^*x_i} < 0$, we have $\frac{dx_i}{dt} > 0$, $\frac{dx^*}{dt} < 0$.[18] The increase in tariff increases R&D investment of home firm, but reduces that of MNE. However, with strategic complements, its effects are ambiguous; $\frac{dx_i}{dt} \gtreqless 0$ and $\frac{dx^*}{dt} \gtreqless 0$. (See Fig.3.)

The trade policy affects not only firm's R&D investments strategy but also MNE's over all investment strategy, which in turn firms' share rivalry in the home market. When R&D investments are strategic substitutes, the protective trade policy in the home market stimulates R&D investments of the home firms' but decreases R&D investment of MNE's, because the increase in export cost promotes internal allocation in MNE by shifting investment money from R&D to FDI. So the technology gap between two countries becomes smaller. On the other hand, the effects of protective policy of the home government are ambiguous when R&D investments are strategic complements.

The general effects of the change in MNE's fund on the market are not clear. However, if the cross derivative of MNE's profit in terms of its fund and its R&D investment is positive, i.e., $\pi^M_{x^*K^*} > 0$, we have

$$\text{(27)}\qquad \begin{aligned} \frac{dx_i}{dK^*} &= \frac{-\pi^i_{x_i K^*}\pi^M_{x^*x^*} + \pi^i_{x_i x^*}\pi^M_{x^*K^*}}{\Delta} < (?)0 \quad \text{if} \quad \pi^i_{x_i x^*} \le (>)0, \\ \frac{dx^*}{dK^*} &= \frac{-\pi^i_{x_i x_i}\pi^M_{x^*K^*} + \pi^i_{x_i K^*}\pi^M_{x^*x_i}}{\Delta} > (?)0 \quad \text{if} \quad \pi^M_{x^*x_i} \le (>)0. \end{aligned}$$

When R&D investments are strategic substitutes, the increase in the fund of MNE directly boosts MNE's R&D investment and indirectly reduces that of home firm's. Then, the technology gap becomes bigger. With strategic complements, if, for example, MNE can raise capital in the host country and invest it into FDI, the gap may be reduced. (See Fig.4.)

Proposition2. With smaller R&D investment by MNE, i.e., R&D investments are strategic substitutes, the protective trade policy of the home government reduces technology gap between two countries. Because, with higher export cost, MNE reduces R&D investment by shifting money from R&D to FDI internally, and home firm increases R&D investments. When R&D investments are strategic complements, the same effect can be obtained if the home government tries to promote inward FDI.

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18 See Appendix 5 for the relation between (26), (27) and the sign of $(2+x^*d')$.

4. Conclusions

As far as money spent for investments is limited for MNE, it must allocate the resource among expansion strategies such as R&D investment and FDI. If it spends more on R&D activity, competitiveness of its exports increases, however, reduction in money spent for FDI reduces subsidiary's in the host country. To analyze the behavior of MNE in deciding its investment strategies, I incorporate these opposite effects in an international oligopoly model. It is shown that it is this internal resource allocation in MNE which determines whether firms' R&D investments are strategic substitutes or strategic complements and, as a result, affects market share rivalry.

The most crucial point of this paper is in the assumption that a fully owned subsidiary does not care the total supply by the family including exports and local production in the host market. The relation between a parent company and its subsidiary must be treated explicitly in the model. Moreover, it is assumed that homogeneous goods are consumed only in the host country. In reality, however, vertical trade and firms' alliance are prevalent so that investments strategies of MNE must be analyzed under bilateral trade mode.[19] The possibility of MNE's technology alliance with a local firm must be studied. Because market structure will be affected if firms jointly conduct R&D investments or collaborate each other complementary. These issues are explored in the next version of this paper.

19 As explained in Brander and Krugman (1983), discriminative price set by oligopolistic firms induces intra-industry, when markets are separated. To save duplication of export costs, which are paid by monopolistic rent, firm may invest directly each other in the export market.

References

Bergstrom, T. C., Varian, H. R., 1985, "When Are Nash Equilibria Independent of the Distribution of Agents' Characteristics?," *Review of Economic Studies*, Vol.52(4), pp.715-18.

Brander, J.A and Krugman, P. R., 1983, "A 'Reciprocal Dumping' Model of International Trade," *Journal of International Economics*, Vol.15, pp.313-23.

Bulow, J. I, Geanakoplos, J. D. and Klemperer, P. D., 1985, "Multimarket Oligopoly: Strategic Substitutes and Complements," *Journal of Political Economy*, Vol.93(3), pp.488-511.

D'Aspremont, D. and A. Jacquemin, 1988, "Cooperative and Noncooperative R&D in Duopoly with Spillovers, " *The American Economic Review*, Vol. 78 (5), pp.1133-37.

Horstmann, I. and Markusen, J.R., 1987, "Strategic investments and the development of multinationals," *International Economic Review*, Vol. 28(1), pp.109-21.

Kamien, M. I., E. Müller and I. Zang, 1992, "Research Joint Venture and R&D Cartels," *The American Economic Review*, Vol. 82 (5), pp.1293-1306.

Markusen, J.R., 2002, *Multinational Firms and the Theory of International Trade*. Cambridge, Mass.: MIT Press.

Petit, M.L. and Sanna-Randaccio, F., 2000, "Endogenous R&D and Foreign direct investment in international oligopolies," *International Journal of Industrial Organization*, Vol. 18, pp. 339-67.

Shy, O., 1995, *Industrial Organization*. Cambridge, Massachusetts, London, England: MIT Press.

Suzumura, K., 1992, "Cooperative and Noncooperative R&D in an Oligopoly with Spillovers," *The American Economic Review*, Vol. 82 (5), pp.1307-20.

Wong, K., 1995, *International Trade in Goods and Factor Mobility*. Cambridge, Mass.: MIT Press.

Appendix

1. From (3)′-(5)′ and (6), the second-order condition for the home firm is -2b and Hessian matrix of MNE is negative definite.

2. From (8) and (9), we have

$$\frac{\partial Y}{\partial t}=-\frac{1}{b(N+3)},\quad \frac{\partial p}{\partial t}=\frac{1}{N+3},\quad \frac{\partial y_i}{\partial t}=\frac{\partial y_F}{\partial t}=\frac{1}{b(N+3)},\quad \frac{\partial y_E}{\partial t}=-\frac{(N+2)}{b(N+3)},$$

$$\frac{\partial Y_{-i}}{\partial x_i}=\frac{\sum_{j,j\neq i}^{N}\partial y_j}{\partial x_i}+\frac{\partial y_E}{\partial x_i}+\frac{\partial y_F}{\partial x_i}=\frac{-(N+1)}{b(N+3)}<0,$$

$$\frac{\partial Y_{-E}}{\partial x^*}=\frac{\sum_i^N \partial y_i}{\partial x^*}+\frac{\partial y_F}{\partial x^*}=\frac{-(N-1)+2x^*d'}{b(N+3)}<0,$$

$$\frac{\partial Y_{-F}}{\partial x^*}=\frac{\sum_i^N \partial y_i}{\partial x^*}+\frac{\partial y_E}{\partial x^*}=\frac{-(N-1)-(N+1)x^*d'}{b(N+3)}<0,$$

$$\frac{\partial^2 Y}{\partial x^{*2}}=\frac{d'-x^{*2}d''}{b(N+3)}<0,\quad \frac{\partial^2 y_i}{\partial x^{*2}}=\frac{-d'+x^{*2}d''}{b(N+3)}>0,$$

$$\frac{\partial^2 y_E}{\partial x^{*2}}=\frac{-d'+x^{*2}d''}{b(N+3)}>0,\quad \frac{\partial^2 y_F}{\partial x^{*2}}=\frac{(N+2)(d'-x^{*2}d'')}{b(N+3)}<0.$$

In (11), $\partial y_F/\partial x^*>(\leq)0$ if $x^*d'>(\leq)-(N+1)/(N+2)$. Since we have $x^*d'\leq 0$ and $1>(N+1)/(N+2)\geq(2/3)$, $\partial y_F/\partial x^*>0$ if $0\geq x^*d'>-(2/3)$. On the other hand, we have $\partial y_F/\partial x^*=0$ with $-(2/3)\geq x^*d'=(N+1)/(N+2)>-1$, $\partial y_F/\partial x^*<0$ if $2+x^*d'\leq 0$ (or, $x^*>0$ and $x^*d'\leq-1$) but the sign of $\partial y_F/\partial x^*$ is ambiguous when $-(2/3)\geq x^*d'>-1$ with $x^*>0$.

3. From (11), (13) and Appendix 2, we have

$$\pi_{x_i}=y_ip'[\frac{\sum_{j,i\neq j}^{N}\partial y_j}{\partial x_i}+\frac{\partial y_E}{\partial x_i}+\frac{\partial y_F}{\partial x_i}]+y_i-x_i=y_i(1+p'\frac{\partial Y_{-i}}{\partial x_i})-x_i=y_i\frac{2(N+2)}{(N+3)}-x_i=0.$$

Differentiate it in terms of (x_i, x_j, x^*, t, K*), respectively, yields

$$\pi_{x_ix_i}=(p'\frac{\partial Y_{-i}}{\partial x_i}+1)\frac{\partial y_i}{\partial x_i}-1=\frac{2(N+2)^2-b(N+3)^2}{b(N+3)^2}<0,$$

$$\pi_{x_ix_j}=p'\frac{\partial Y_{-i}}{\partial x_i}\frac{\partial y_i}{\partial x_j}+\frac{\partial y_i}{\partial x_j}=-\frac{2(N+2)}{b(N+3)^2}<0,$$

$$\pi_{x_ix^*}=p'\frac{\partial Y_{-i}}{\partial x_i}\frac{\partial y_i}{\partial x^*}+\frac{\partial y_i}{\partial x^*}=-\frac{2(N+2)(2+x^*d')}{b(N+3)^2},$$

$$\pi_{x_it}=p'\frac{\partial Y_{-i}}{\partial x_i}\frac{\partial y_i}{\partial t}=\frac{2(N+2)}{b(N+3)^2}>0,$$

$$\pi^i_{x_iK^*}=(p'\frac{\partial Y_{-i}}{\partial x_i}+1)\frac{\partial y_i}{\partial K^*}+y_Ep'\frac{\partial^2 Y_{-i}}{\partial x_i\partial K^*}=\frac{2(N+2)d'}{b(N+3)^2}<0.$$

4. Similarly, from 3 (11), (16) and Appendix 2, we have

$$\pi^M_{x^*} = y^* + y_E(p'\frac{\partial Y_{-E}}{\partial x^*}+1) + y_F(p'\frac{\partial Y_{-F}}{\partial x^*}+1+x^*d')$$
$$= y^* + \frac{2y_E[(N+1)-x^*d']}{(N+3)} + \frac{2y_F[(N+1)+(N+2)x^*d']}{(N+3)}$$
$$= y^* + \frac{2}{(N+3)}\{y_E[(N+1)-x^*d'] + y_F[(N+1)+(N+2)x^*d']\} = 0.$$

Differentiate it in terms of x^*, x_i, t and K^*, respectively, yields

$$\pi^M_{x^*x^*} = \frac{\partial y^*}{\partial x^*} + [p'(\sum_i^N \frac{\partial y_i}{\partial x^*} + \frac{\partial y_F}{\partial x^*}) + 1]\frac{\partial y_E}{\partial x^*} + [p'(\sum_i^N \frac{\partial y_i}{\partial x^*} + \frac{\partial y_E}{\partial x^*}) + 1 + x^*d']\frac{\partial y_F}{\partial x^*} + p'y_E(\sum_i^N \frac{\partial^2 y_i}{\partial x^{*2}} + \frac{\partial^2 y_F}{\partial x^{*2}})$$
$$+ p'y_F(d' - x^{*2}d'' + \sum_i^N \frac{\partial^2 y_i}{\partial x^{*2}} + \frac{\partial^2 y_E}{\partial x^{*2}})$$
$$= \frac{1}{2b^*} + \frac{2\{[(N+1)-x^*d']^2 + [(N+1)+(N+2)x^*d']^2\}}{b(N+3)^2} - \frac{G\{2y_E + y_F[b(N+3)-(N+1)]\}}{N+3} < 0,$$

where $G = d' - x^{*2}d'' < 0$ *from* $(A-6)$.

$$\pi^M_{x^*x_i} = [p'(\sum_i^N \frac{\partial y_i}{\partial x^*} + \frac{\partial y_F}{\partial x^*}) + 1]\frac{\partial y_E}{\partial x_i} + [p'(\sum_i^N \frac{\partial y_i}{\partial x^*} + \frac{\partial y_E}{\partial x^*}) + 1 + x^*d']\frac{\partial y_F}{\partial x_i}$$
$$= -\frac{2(N+1)(2+x^*d')}{b(N+3)^2} \gtreqless 0 \quad \Leftrightarrow \quad 2 + x^*d' \lesseqgtr 0,$$

$$\pi^M_{x^*t} = [p'(\sum_i^N \frac{\partial y_i}{\partial x^*} + \frac{\partial y_F}{\partial x^*}) + 1]\frac{\partial y_E}{\partial t} + [p'(\sum_i^N \frac{\partial y_i}{\partial x^*} + \frac{\partial y_E}{\partial x^*}) + 1 + x^*d']\frac{\partial y_F}{\partial t}$$
$$= \frac{2}{b(N+3)^2}[-(N+1)^2 + 2(N+2)x^*d'] < 0,$$

$$\pi^M_{x^*K^*} = (p'\frac{\partial^2 Y_{-E}}{\partial x^*} + 1)\frac{\partial y_E}{\partial K^*} + y_E p'\frac{\partial^2 Y_{-E}}{\partial x^*\partial K^*} + (p'\frac{\partial^2 Y_{-F}}{\partial x^*} + 1 + x^*d')\frac{\partial y_F}{\partial K^*} + y_F(p'\frac{\partial^2 Y_{-F}}{\partial x^*\partial K^*} + x^*\frac{\partial d'}{\partial K^*})$$
$$= -\frac{2d'\{(N+1)^2 + [1+(N+2)^2]x^*d'\}}{b(N+3)^2} - \frac{2x^*d''}{N+3}(y_E - y_F).$$

5. The signs of $\pi^i_{xx^*}$ and $\pi^M_{x^*x}$ depend on that of $(2+x^*d')$ in (20) and (23). Then, (26) becomes

$$\frac{dx_i}{dt} > 0 \ \ and \ \ \frac{dx^*}{dt} < 0 \quad if \quad 2+x^*d' > 0 \ \Leftrightarrow \ \pi^i_{x_ix^*}, \pi^M_{x^*x_i} < 0,$$
$$\frac{dx_i}{dt} > 0 \ \ and \ \ \frac{dx^*}{dt} < 0 \quad if \quad 2+x^*d' = 0 \ \Leftrightarrow \ \pi^i_{x_ix^*}, \pi^M_{x^*x_i} = 0,$$
$$\frac{dx_i}{dt}\ ? \ \ and \ \ \frac{dx^*}{dt}\ ? \quad if \quad 2+x^*d' < 0 \ \Leftrightarrow \ \pi^i_{x_ix^*}, \pi^M_{x^*x_i} > 0,$$

And if $\pi^M_{x^*K^*} > 0$, then (27) becomes

$$\frac{dx_i}{dK^*} < 0 \ \ and \ \ \frac{dx^*}{dK^*} > 0 \quad if \quad 2+x^*d' > 0 \ \Leftrightarrow \ \pi^i_{x_ix^*}, \pi^M_{x^*x_i} < 0,$$
$$\frac{dx_i}{dK^*} < 0 \ \ and \ \ \frac{dx^*}{dK^*} > 0 \quad if \quad 2+x^*d' = 0 \ \Leftrightarrow \ \pi^i_{x_ix^*}, \pi^M_{x^*x_i} = 0,$$
$$\frac{dx_i}{dK^*}\ ? \ \ and \ \ \frac{dx^*}{dK^*}\ ? \quad if \quad 2+x^*d' < 0 \ \Leftrightarrow \ \pi^i_{x_ix^*}, \pi^M_{x^*x_i} > 0.$$

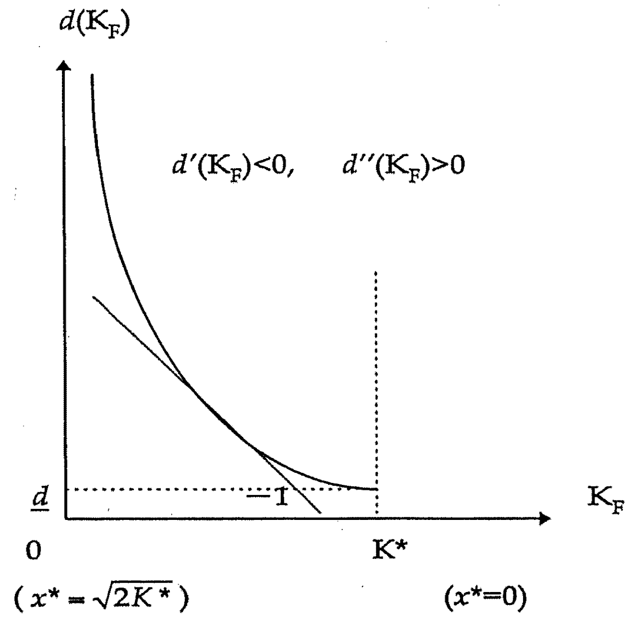

Fig. 1 The amount of FDI, K_F, and distribution cost of the subsidiary, $d(K_F)$.

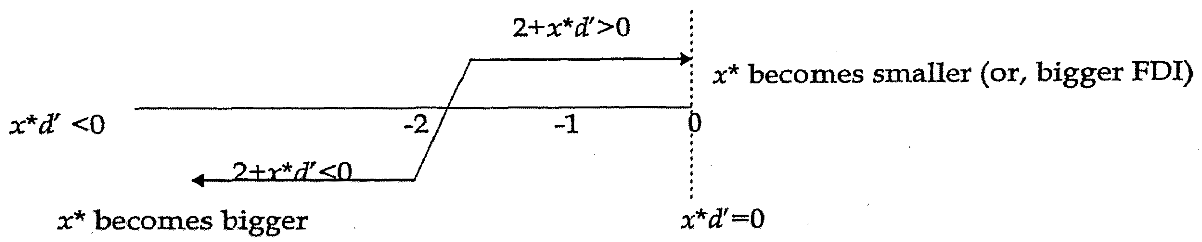

Fig.2a R&D investment of MNE (x^*)

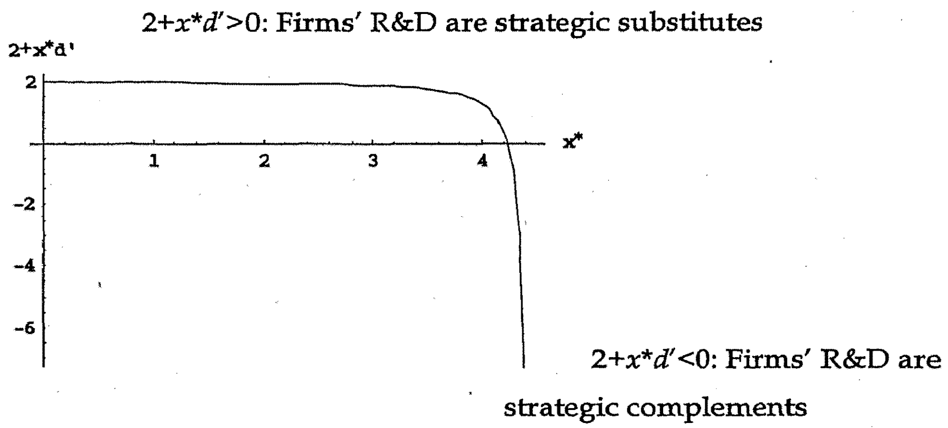

Fig.2b R&D investment of MNE and strategic substitutes (complements):
[K*=10, $d = 1/\sqrt{K_F(x^*)}$]

The smaller MNE's R&D investment (x^*), the bigger ($2+x^*d'$) becomes.

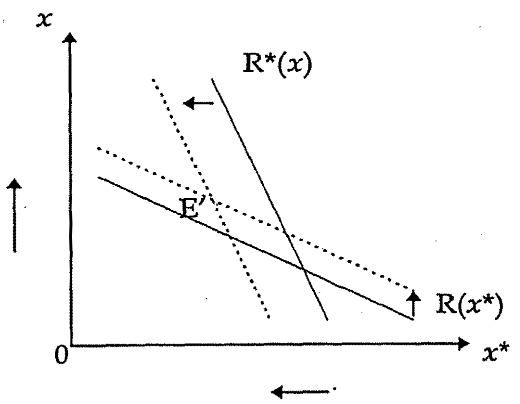

Fig. 3.1 Increase in export cost when R&D investments are strategic substitutes: $2+x^*d'>0$

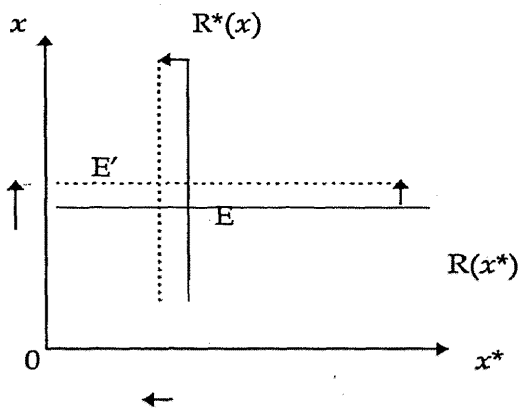

Fig. 3.2 $2+x^*d'=0$:

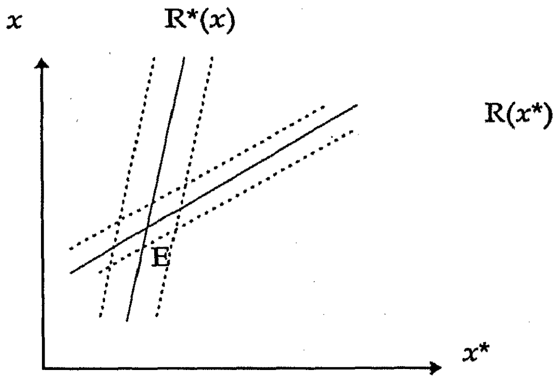

Fig. 3.3 Increase in export cost when R&D investments are strategic complements: $2+x^*d'<0$

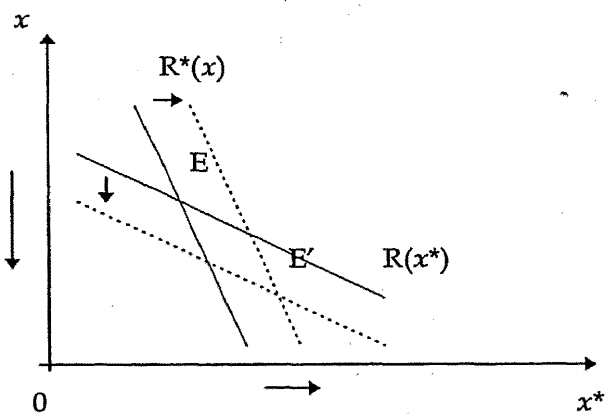

Fig. 4a Increase in MNE's fund when R&D investments are strategic substitutes: $2+x^*d'>0$

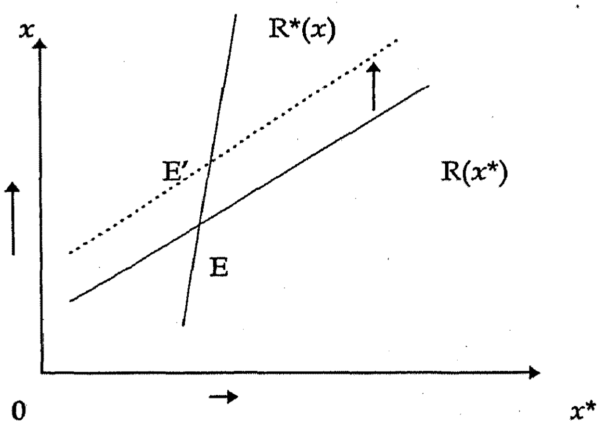

Fig. 4b Increase in MNE's fund when R&D investments are strategic complements: $2+x^*d'<0$