PROCESS INNOVATION AND STRATEGIC TRADE POLICY

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Abstract:

The outcome of R&D activities for product or process innovation depend on the technological level of the firm, its investment level in R&D, the effort levels of the persons involved in such R&D activities and some other factors. In this paper we try to incorporate these aspects of firms' R&D activity in finding optimal strategic trade policies. While the present paper is not particularly dealing with the choice between the two, but we show that product innovation is beneficial for the firm only under certain conditionalities, whereas process innovation is always beneficial. We also show that the optimal policy of either of the governments depends crucially on the exogenous variables like the qualities of the two products, the technology level of the production process and also the parameters representing the R&D effort of the home firm.

INTRODUCTION

When a market comprises two firms, which are located in two different countries and produce vertically differentiated goods, price competition among them would result in higher prices being charged for both the goods for higher degree of differentiation and, in consequence, a shrink in the market sizes of both the firms. On the other hand, the lower is the quality gap between the two products, the higher is the intensity of the competition and hence lower would be the prices charged for the products. This would give rise to the total market served but would also adversely affect the profit margin of the firms. Now, if the low quality firm (i.e. the firm that produces the lower quality good) undertakes R&D programme for further quality improvement (i.e. product innovation), but the high quality firm (that produces the higher quality good) does not, the result could be an increase in the substitutability of the two products unless the low quality firm leapfrogs its rival's product quality to reach the other end of the quality spectrum. Even in this latter case also, there could be an increase in substitutability of the two products if the quality of the foreign firm’s product is too high. If, however, the low quality firm does R&D for cost reduction purposes (i.e. process innovation), it can enjoy a higher market size by charging post facto lower price for its goods. So, apparently the low quality firm has a strong incentive to do process innovation rather than product innovation, as far as its R&D activity is concerned.

In this study, where we consider an uncovered market, we are able to show that process innovation is beneficial, though we do not get such clear result for product innovation. We study here the strategic trade policies when the low quality firm undertakes R&D for process innovation. It would have been interesting to study the strategic trade policy in a scenario where both the firms undertake R&D programmes for product innovation or process innovation and choose the qualities or technology levels strategically. But, in this study, as a first step to that end, we restrict ourselves to the case where the low quality firm alone undertakes such R&D programme.

Stackelberg leader in the international market share rivalry. However, this argument is based on the assumption of homogeneous product duopoly. Most of the studies in this literature are developed on this assumption (in some studies the market is considered as oligopolistic). Dixit(1984) considers reciprocal trading countries wherein he examines the impact of trade and industrial policies, including antitrust policy, on market shares of the firms. Eaton and Grossman (1986) develops a more general third country model than was considered in Brander and Spencer (1985) and show that the optimal strategic trade policy depends crucially on the nature of the competition between the firms. Dixit and Grossman (1986) considers targeting aspects of such strategic trade policy, while Cooper and Riezman (1989) demonstrate the impact of uncertainty on such optimal policy choice. Though the argument of strategic trade policy was gaining ground since the beginning of 1980s, it was not until the late eighties that the cases of product differentiation were given due consideration in the literature. Gruenspecht (1988) considers a horizontal product differentiation model to analyse welfare effects of various export promotion policies. Bagwell (1991) considers the pricing behaviour of a new product monopolist under export subsidy policy of the government and argues that export subsidies reduce the distortion in pricing the high-quality exports and increase the probability of low-quality export. He shows that the incentive of the low quality monopolist to send a wrong signal of its quality to be high, by charging high price, is reduced in the presence of such export subsidy.

Many a studies examined various types of trade policies when one or both the firms undertake R&D. Grossman and Helpman (1994) surveys the relationship between technology and trade that covers the old literature on trade where technology was taken as exogenous, as also the recent studies where the technological progress was endogenized by incorporating the concept of learning-by-doing or investments in research and development. Gries and Wigger (1993) studies the upgrading process of a backward country through imitation and shows that pure imitation may support the upgrading process but cannot help Catch-Up in the long run. They show that a full closure of the technological gap requires innovation rather than imitation. However, on a strategic plane, it is not the R&D effort for innovations by firms alone that plays a crucial role for its success in international trade, but also the government intervention which gives its firm a competitive edge over its rival. Marin (1995) studies the Austrian development process and shows that Austria, despite its share of expenditure for research and development in GDP being small, was among the countries with the fastest convergence rate mainly because of its resource endowments, international knowledge spillovers, learning and government policies.[1] Spencer and Brander (1983) shows that a R&D subsidy to the domestic firm by the home government puts the firm at a Stackelberg leader position in the international market share rivalry. When combined with export subsidy, imposition of R&D tax becomes an optimal policy which corrects the firms bias towards excessive investments in research and development.[2] Miyagiwa and Ohno (1997) considers an intertemporal model of stochastic innovation in strategic context and shows that at low or high degree of appropriability of the new technology, R&D taxes are optimal, but at intermediate degree, R&D subsidies are optimal. Leahy and Neary (1996) considers the timing of moves and the ability of agents to commit intertemporally. It shows that export subsidy, R&D subsidy and government welfare are higher when government commitment is credible than in the dynamically consistent equilibrium without commitment. Bagwell and Staiger (1994) considers uncertainty in the R&D outcome while evaluating the case for R&D subsidies in export sectors. They show that there is a strategic incentive to subsidise R&D but a corrective incentive to tax it, irrespective of the firms choosing prices or quantities, when R&D reduces the expected costs in the particular sense of first-order stochastic dominance. On the contrary, when R&D increases the riskiness of the cost distribution, the result reverses.

Up-gradation of product quality or reduction of production cost, i.e., product innovation or process innovation, both require the firms to invest considerably in research and development activities. The outcome of such R&D activities may well depend on the technological level of the firm, its investment level in R&D, and the effort of persons involved in such R&D activities and some other factors. The above studies do not take all of such factors into consideration while examining the strategic studies (Bonanno and Howarth (1998), Rosenkranz (1996), Bertschek (1995) etc.). But none of these studies consider the strategic aspect of trade policy while analysing this choice. While the present paper is not particularly dealing with the choice between the two, but we show that product innovation is beneficial for the firm only under certain conditionalities, whereas process innovation is always beneficial.

The rest of the paper is arranged as follows. We begin with the basic model of the article in section 2 followed by section 3 where we determine the market shares of the two firms in absence and presence of government interventions when the low quality firm does not undertake any R&D activity. In section 4 we consider the process innovation activity by the low quality firm and accordingly determine the optimal strategic trade policies for the governments of the exporting countries. The paper ends with some concluding remarks in section 5.

BASIC MODEL

We employ here the parameters q, ρ and P, where q is the quality of a product, ρ is a kind of index for the consumers depending on their respective income levels and corresponding valuations of a satisfactory product, and P is the price of the product. Consumers, each with unit demand, are also assumed to be in a uniform distribution. We further assume that the index for the consumers, ρ, varies in the range of [0, 1]. The net expected utility of a consumer with index ρ from consumption of a product of quality q and price P can, therefore, be written as

$$\begin{aligned} U(\rho) &= q(\rho - P) + (1 - q)(-P) \\ &= q\rho - P \qquad \ldots\ldots(1) \end{aligned}$$

Let us assume that the world comprises three countries – two producing countries and one consuming country. We name the two producing countries as home country and foreign country, while the consuming country is named as the third country. We further assume that the producing countries have no domestic consumption so that all the products produced by them are exported to the third country, which is assumed not to have any production facility so that its consumption depends solely on the supplies received from the two producing countries. We consider here an international duopoly that consists of one firm in each of these two producing countries. The quality, q_1, of the home country product is assumed to be lower than that of the foreign country product, q_2. While the two producing countries are assumed to have same technological capabilities, the argument behind such differentiation in qualities could be given in two ways. The price equilibrium in a duopoly under vertical product differentiation is characterised by the two firms choosing two extreme product qualities and the first mover is assumed to be the higher quality producer (Tirole 1989) and, accordingly, the foreign firm is assumed here to be the first mover in the choice of quality. One can further see that even if the two countries have the same levels of technological know-how, the availability of right inputs, or the lack of it, could make all the differences as far as quality of the two products are concerned. In this perspective, we assume here the home country to be weaker than the foreign country.

Let P_1 and P_2 be the prices of the products produced by the home firm (HF) and the foreign firm (FF) respectively. The consumer, who is indifferent between consuming either of the goods as he derives the same net expected utility by consuming either of the goods, has ρ value as

$$\rho^* = (P_2 - P_1) / (q_2 - q_1). \qquad \ldots.(2)$$

Therefore, the consumers having ρ values lower than ρ^* will consume lower quality good if they gain a positive net expected utility out of consumption and the consumers with ρ values higher than ρ^* will consume the higher quality good. The consumer, who is indifferent between non-consumption and where $$U(\rho_0) = q_1 \rho_0 - P_1 = 0. \quad ...(3)$$

Therefore, the demand functions, D_1 & D_2, faced by the home and the foreign firms respectively are given by

$$HF: \quad D_1 = \int_{\rho^0}^{\rho^*} d\rho = (q_1 P_2 - q_2 P_1) / q_1 (q_2 - q_1) \quad \ldots(4)$$

$$FF: \quad D_2 = \int_{\rho^*}^{1} d\rho = 1 - (P_2 - P_1)/ (q_2 - q_1). \quad \ldots(5)$$

Let α be the parameter that represents the technology levels of a firm such that α assumes higher values when the firm has backward technology and vice-versa. We normalise α to vary in the range of [0, 1], where α is 0 when the technology is very advanced and it is 1 for extremely backward technology. As mentioned above, both the firms have the same levels of technology, so the values of α for these two firms would be same. Let us now define the marginal cost of production of a firm as 'αq', where α is the technology level of the firm concerned and q, the quality of the product produced by the firm. So, the marginal cost faced by the home firm is αq_1 and the same for the foreign firm is αq_2.

The home firm's R&D effort to reduce its marginal cost of production is modeled as below. Let y be the probability of success of such R&D effort by the home firm. We define its ex-post marginal cost of production as $\alpha' q_1$, where

$$\alpha' = (1 - y)\, \alpha, \quad y \in (0, 1). \quad \ldots(6)$$

We take the R&D cost function to be of the following form:

$$C (y) = cy^2 + f \quad \ldots(7)$$

where 'f' is the fixed cost and 'c', a parameter that is inversely related to the effort level of the firm's R&D group. This relationship implies that to achieve a certain level of probability of success, the R&D cost will be higher if the effort level of the R&D group of the firm is low and vice-versa. As we consider here a one period game only, let us normalise 'f' to zero. This is because existence of a very high fixed cost may not make the R&D effort profitable at all in the single period game, which would rather be more realistic when considered in the cases of dynamic games. So the R&D cost function as considered in this model is given by

$$C (y) = cy^2. \quad ....(8)$$

From (8), we have $C'(y) \geq 0$ and $C''(y) > 0$ as $c > 0$. The second inequality characterises the diminishing return of the cost function. We further assume that $C(0) = 0$.

The firms are assumed to be competing in prices in this model. Therefore, the market shares of the two firms in the third country market are determined by the prices charged by them in equilibrium. In absence of any R&D effort by the home firm, the game involving government intervention comprises two stages. In the first stage, the two producing country governments decide on their respective optimal levels of export subsidy or tax, and in the second stage the firms face each other in the third country market. Here we are not considering the cases where the third country government intervenes in the market. When the home firm undertakes R&D programme for process innovation, the game comprises three stages. In this case the governments decide on their respective optimal policies in the first stage, the home firm decides about its optimal level of R&D at the second stage and this is followed by the third stage rivalry of the firms in the third country market. In order to have sub-game perfect Nash equilibrium, the games

NO R&D EFFORT BY HOME FIRM

The case without any government intervention.

In this case, where neither does the home firm undertake any R&D activities, nor do the governments pursue any interventionist measures, utilising the demand functions as in (4) and (5) above, we get the profit functions, Π_1 & Π_2, of the home and the foreign firm respectively as follows:

HF : $\Pi_1 = (P_1 - \alpha q_1)(q_1P_2 - q_2P_1) / \{q_1(q_2 - q_1)\}$

FF : $\Pi_2 = (P_2 - \alpha q_2)\{1 - (P_2 - P_1)/(q_2 - q_1)\}$. ….(9)

Here, the game has only one stage that is of price competition of the two rival firms in the third country market. The Nash equilibrium prices of this game are, therefore, given by

HF : $P_1^* = \{3\alpha q_1q_2 + q_1(q_2 - q_1)\}/(4q_2 - q_1)$

FF : $P_2^* = q_2\{2\alpha q_2 + 2(q_2 - q_1) + \alpha q_1\}/(4q_2 - q_1)$ ....(10)

and accordingly the demands faced by the two firms in equilibrium are given by

HF : $D_1^* = (1 - \alpha)q_2/(4q_2 - q_1)$

FF : $D_2^* = 2(1 - \alpha)q_2 / (4q_2 - q_1)$ ....(11)

The equilibrium profits of the two firms, in this case, are

HF : $\Pi_1^* = (1 - \alpha)^2q_1q_2(q_2 - q_1)/(4q_2 - q_1)^2$

FF : $\Pi_2^* = 4(1 - \alpha)^2q_2^2(q_2 - q_1)/(4q_2 - q_1)^2$ ….(12)

The equilibrium market size is

$D^* = D_1^* + D_2^* = 3(1 - \alpha)\, q_2/(4q_2 - q_1)$ ....(13)

that leaves a portion of $(q_2 - q_1 + 3\alpha q_2)/(4q_2 - q_1)$ of the total market uncovered.

Let us now state some of the interesting results obtained from some closer inspection of the above expressions.

Proposition 1. The market size increases with the increase in the home firm product quality. Moreover, such increase in home firm product quality would have larger positive effect on the market share of the foreign firm than on its own market share.

Proof : From (10), (11) and (13) we can see that

a) $dD/dq_1 = 3(1 - \alpha)q_2 / (4q_2 - q_1)^2 > 0$,

b) $dP_1/dq_1 < 1$

and c) $dD_1/dq_1 > 0$, $dD_2/dq_1 > 0$ ……..(14)

While (a) substantiate the first result in the above proposition, (b) and (c) provide the explanation for the same. The result in (b) implies that an increase in the quality level of the home firm product would result in a relatively lower level of increase in the price of the corresponding good. This is because, rise in the home firm product quality would increase the substitutability of the two products thereby intensifying the price competition. This would prevent the home firm to increase the price of its product proportionate to the increase in its quality level. Thus, the relatively lower price compared to the increased quality of the home firm product would enable more consumers, who so far abstained from consumption due to negative net utility out of consumption, to consume this good. Similarly, some of the consumers of the lower quality good would now prefer to consume the higher quality good due to fall in price of the higher quality good as well. These are clear from the following expressions:

$d\rho_0/dq_1 < 0$ and $d\rho^*/dq_1 < 0$. ………(15)

In addition to this, we have

This says that the rise in the home firm product quality would have larger positive impact on the market share of the foreign firm rather than on its own market share. This proves the second part of the above proposition.
On the contrary, increase in the foreign firm quality would have negative effect on the size of the markets faced by each of the firms as

$$dD_1/dq_2 < 0, \ dD_2/dq_2 < 0. \qquad \text{.....(17)}$$

This is because the price competition would be less intensified due to higher degree of product differentiation in the event of rise in the foreign firm product quality. This would increase the prices of both the goods thereby reducing the total market size. In fact, such increase in the foreign firm quality would lead to increase the profit margins of both the firms as is depicted by the following expressions:

$$d\{P_1 - \alpha q_1\}/dq_2 = 3q_1^2(1 - \alpha)/(4q_2 - q_1)^2 > 0$$
$$d\{P_2 - \alpha q_2\}/dq_2 = 2(1 - \alpha)(4q_2^2 - 2q_1q_2 + q_1^2)/(4q_2 - q_1)^2 > 0 \qquad \text{....(18)}$$

Hence follows proposition 2.

Proposition 2. Increase in the quality of the foreign firm product would have a positive impact on the profit margins per unit of demand for both the firms and reduce the total market size.

The impact of the rise in the quality of the home firm product on its profit margin per unit of demand is ambiguous. However, closer inspection of the expression

$$d\{P_1 - \alpha q_1\}/dq_1 = (1 - \alpha)(4q_2^2 - 8q_1q_2 + q_1^2)/(4q_2 - q_1)^2 \qquad \text{....(19)}$$

reveals that *the impact is negative when both q_1 and $(q_2 - q_1)$ are low or if q_1 is very high. The impact is positive when q_1 is low but $(q_2 - q_1)$ is high*. The reason for such result is that raising the home firm product quality when the quality gap of the two products is already at a low level would make the competition more intensive due to increase in the substitutability of the two products. This would put pressure on their price levels resulting in a lower level of profit margins for both the firms, especially the home firm, per unit of the demand faced. But when the quality gap is high, the home firm gets some manoeuvrability as far as the quality is concerned as it faces less intensive competition from its foreign counterpart. Moreover, when q_1 itself is very high, the possibility of quality gap being high becomes low, so the impact of raising q_1 to even higher level is bound to be negative on its profit margin. Owing to such ambiguous impact of the rise in q_1 on $\{P_1 - \alpha q_1\}$, the impact of the same on the home firm's profit is also ambiguous despite the fact that such rise in q_1 has positive impact on the demand faced by the home firm.

However, if instead, the firms upgrade their technology for producing the products, their profits will increase. As shown in the following proposition, lowering α would have a positive impact on the profits of both the firms.

Proposition 3. Upgrading technology would have a positive impact on the profits of both the firms.

Proof : From (12) we see that

$$d\Pi_i /d\alpha < 0 \qquad \text{..........(17)}$$

where i = 1, 2 for home and foreign firm respectively. This implies that the lower is the value of α, the higher would be the profits of both the firms. In other words, the more advanced is the level of technology used by the firms, the higher are their profits. This is because, use of advanced technology would reduce the marginal costs of production, which in consequence would lower the prices charged for both the goods. This, while giving rise to the demands faced by the firms, would also increase the profit margin per unit of demand for both the firms.

or not, crucially depends on the ex-ante quality of the home firm product, as also on the quality of the foreign firm product. Secondly, process innovation, i.e. R&D for cost reduction, would certainly benefit the home firm by increasing it's profit irrespective of the quality levels of both the products as is implied by (17).

In the consequent analysis, we would consider the process innovation through R&D activity, rather than product innovation, by the home firm. Moreover, in the analysis of comparative statics, the implicit assumption is that changes, whether through product innovation or process innovation, are cost-less. But, in reality, the R&D cost for such product innovation or process innovation may very well wipe out the resultant profit achieved through such R&D activity in the short run, which may, however, result in higher profits in the longer run. In section 4.4 we will analyse the scenario where the home firm undertakes R&D activity for process innovation with a R&D cost function that is characterised by diminishing returns.

The game with Government intervention

In this sub-section, we will consider the case where the governments of the two producing countries intervene in the market. In this case the game comprises two stages. In the first stage the governments decide about their optimal levels of subsidy/tax on their respective exports. In the second stage the firms face each other in the third country market. Let s and t be the specific export subsidies extended by the home and foreign governments respectively to their respective firms. Therefore, the profit functions of the two firms at the second stage of the game are

$$\text{HF}: \Pi_1^s = (P_1 - \alpha q_1 + s)(q_1P_2 - q_2P_1)/\{q_1(q_2 - q_1)\}$$
$$\text{FF}: \Pi_2^s = (P_2 - \alpha q_2 + t)\{1 - (P_2 - P_1)/(q_2 - q_1)\} \qquad \text{.....(18)}$$

This gives us the equilibrium price levels at this stage of the game for given s and t as

$$\text{HF}: P_1^{s*} = \{3\alpha q_1q_2 + (q_2 - q_1)q_1 - tq_1 - 2sq_2\}/(4q_2 - q_1)$$
$$\text{FF}: P_2^{s*} = q_2\{2\alpha q_2 + 2(q_2 - q_1) + \alpha q_1 - 2t - s\}/(4q_2 - q_1) \qquad \text{.....(19)}$$

Accordingly, we get the demands faced by the two firms as

$$\text{HF}: D_1^{s*} = q_2\{1 - \alpha - t/(q_2 - q_1) + s(2q_2 - q_1)/q_1(q_2 - q_1)\}/(4q_2 - q_1)$$
$$\text{FF}: D_2^{s*} = \{2(1 - \alpha)q_2 + t(2q_2 - q_1)/(q_2 - q_1) - sq_2/(q_2 - q_1)\}/(4q_2 - q_1). \qquad \text{....(20)}$$

Therefore, in the equilibrium, the total market served under this case is

$$D^{s*} = \{3(1 - \alpha)\, q_2 + t + 2sq_2/q_1\}/(4q_2 - q_1). \qquad \text{.....(21)}$$

From (21), it is evident that the subsidy policy by either or both of the governments would have positive impact on the equilibrium market size. Moreover, as

$$|\, dD^{s*}/ds \,| > |\, dD^{s*}/dt \,|, \qquad \text{.....(22)}$$

the interventionist measures of the home government would have larger impact, be it positive or negative, on the total market covered in the third country. The impact would be positive when both the governments pursue export subsidy programmes, where the third country consumers would benefit more from home government intervention than that by the foreign country government. On the contrary, the impact would be negative when both the governments pursue export tax programmes. In this case, the impact of home government intervention would be more harmful to the third country consumers compared to the foreign government intervention.

Now, in the first stage of the game, the two governments decide on the optimal intervention policies. The social welfare function for the home government, in absence of any domestic consumption, becomes

$$+s(2q_2 - q_1)\}/\{q_1(q_2 - q_1)(4q_2 - q_1)^2\} \quad \text{.....(23)}$$

Similarly, for the foreign government, the social welfare function could be written as

FG : $G_f(s, t) = \Pi_2^s - t\,D_2^s$

$$= q_2\,\{2(1 - \alpha)(q_2 - q_1) - 2t - s\}\{2(1 - \alpha)q_2(q_2 - q_1) - sq_2 + t(2q_2 - q_1)\}/\{(q_2 - q_1)(4q_2 - q_1)^2\} \quad \text{.....(24)}$$

The optimal values of s and t at the Nash equilibrium of the first stage game of the two governments, where both the governments maximize their respective social welfare functions, are obtained as

HG : $s^* = 2q_1^2(1-\alpha)(4q_2 - q_1)(q_2 - q_1)/\{q_1^3 - 16q_2(2q_2 - q_1)^2\}$

FG : $t^* = (1 - \alpha)(q_2 - q_1)\{q_1^3 + 8q_1q_2(2q_2 - q_1)\}/\{q_1^3 - 16q_2(2q_2 - q_1)^2\}$ ....(25)

From (25), it is clear that the numerators in the values of both s^* and t^* are positive, while denominator, which is same in both the values, is negative. Therefore, *the optimal policies for both the governments would be to impose specific export tax on their respective firms*. This is the same result as was shown in Eaton and Grossman(1986). Our aim in this paper, however, is not just to prove the same result again, rather to give an example where this result is not so robust. This is shown in section 4.4 where the home firm undertakes R&D for process innovation and both the governments intervene in the market.

THE CASE WITH THE R&D ACTIVITIES OF THE HOME FIRM.

As explained in section 3.1 above, we will be considering the case where the home firm undertakes R&D programme for process innovation only. The foreign firm is assumed not to undertake any R&D activities of any kind whatsoever, neither product innovation, nor process innovation. So, the foreign firm continues to produce products of quality q_2 at a marginal cost of αq_2. The specifications of home firm's R&D activities, as already mentioned in section 4.2 above, are given below.

Ex-post marginal cost of production for the home firm = $\alpha' q_1$,

where $\alpha' = (1 - y)\alpha$, $y \in (0, 1)$ being the probability of success of it's R&D effort. The R&D cost function is given as

$$C(y) = cy^2 \quad \text{....(26)}$$

where c (> 0) is a parameter that varies inversely with the effort level of the firm's R&D group so that c is high when the R&D group put in lower level of effort and vice-versa. Let us assume that c has a lower limit, say $\underline{c}$, implying that the effort level of the R&D group of the firm cannot really bring down the cost of R&D to a level of zero.

The case without any government intervention.

First let us consider the case where none of the two producing country governments intervenes in the market. This game, therefore, has two stages. In the first stage, the home firm decides about its optimal level of R&D and in the second stage the home firm faces the foreign firm in a market share rivalry in the third country. The profit functions of the firms at the second stage of the game are written as follows.

HF : $\Pi_1^R = (P_1 - \alpha' q_1)(q_1P_2 - q_2P_1)/\{q_1(q_2 - q_1)\} - C(y)$

FF : $\Pi_2^R = (P_2 - \alpha q_2)\,\{1 - (P_2 - P_1)/(q_2 - q_1)\}$ ...(27)

The equilibrium prices in this case are given by

HF : $P_1^{R*} = q_1\{(2\alpha' + \alpha)q_2 + q_2 - q_1\}/(4q_2 - q_1)$

FF : $P_2^{R*} = q_2\{2\,\alpha q_2 + \alpha' q_1 + 2(q_2 - q_1)\}/(4q_2 - q_1)$. ...(28)

$$FF\ :\ D_2^{R*} = q_2\{2(q_2 - q_1) - 2\alpha q_2 + (\alpha' + \alpha)q_1\}/(q_2 - q_1)(4q_2 - q_1). \qquad ...(29)$$

The equilibrium profits of the firms at this stage are

$$HF\ :\ \Pi_1^R = q_1q_2\{(1 - \alpha)(q_2 - q_1) + (2q_2 - q_1)\,\alpha y\}^2 /(q_2 - q_1)(4q_2 - q_1)^2 - cy^2$$

$$FF\ :\ \Pi_2^R = q_2\{(\alpha' + \alpha)q_1 + 2(q_2 - q_1) - 2\alpha q_2\}/(q_2 - q_1)(4q_2 - q_1)^2. \qquad \ldots(30)$$

Now, in the first stage of the game, the home firm decides about the optimal level of R&D by maximizing its profit with respect to y, the probability of success in R&D. The idea is that, given the direct relationship between the R&D cost and the probability of success in R&D as in (26) above, determination of optimal level of R&D expenses boils down to determining the optimal level of probability of success itself. This procedure is specific to this model only.

The objective function of the home firm in the first stage of the game is

$$\max_{y}\ \Pi_1^R = q_1q_2\{(1 - \alpha)(q_2 - q_1) + (2q_2 - q_1)\,\alpha y\}^2 /\{(q_2 - q_1)(4q_2 - q_1)^2\} - cy^2$$

subject to $0 \le y \le 1$. $\qquad \ldots.(31)$

Utilising the Kuhn-Tucker conditions for maximization, we get the optimal value of y as

$$y^* = \alpha q_1q_2(1 - \alpha)(q_2 - q_1)(2q_2 - q_1) /\{c(q_2 - q_1)(4q_2 - q_1)^2 - \alpha^2 q_1q_2(2q_2 - q_1)^2\} \qquad \ldots.(32)$$

This shows that the lower is the value of c, higher is the optimal probability of success in R&D. However, if c is too low, then y^* may very well be negative and its value may well exceed unity. We can possibly define $\underline{c}$ here in such a way that y^* never becomes a negative number, which is possible if

$$\underline{c} = \alpha^2 q_1q_2\,(2q_2 - q_1)^2 / (q_2 - q_1)(4q_2 - q_1)^2\ . \qquad \ldots.(33)$$

As all the parameters in the right hand side of (33) are exogenous, $\underline{c}$ is also exogenous. While for higher c's, y^* is definitely less than unity, there may be some values of c for which y^* may exceed unity. In these latter cases, we will take y* = 1. Though $\underline{c}$ could also be defined in such a way that y* never exceeds unity, we would like to have results valid for a wider range of c.

The game under interventions by the producing country governments

We now consider the case where the two exporting countries intervene in the market. In this case the game consists of three stages. In the first stage, the two producing country governments decide on their respective optimal intervention policies such as specific export subsidy or tax. In the second stage, the home firm determines its optimal level of R&D efforts towards process innovation. In the third stage, the home firm faces the foreign firm in a price competition in the third country market. Let s and t be the specific export subsidies provided by the home and the foreign governments respectively to their respective firms. Let P_1, P_2 be the prices charged and D_1, D_2 the demands faced by the home and foreign firms for their goods respectively.

The profit functions of the two firms in the third stage of the game are given as

$$HF\ :\ \Pi_1^{RS} = (P_1 - \alpha' q_1 + s)\{(q_1P_2 - q_2P_1)/q_1(q_2 - q_1)\} - C(y)$$

$$FF\ :\ \Pi_2^{RS} = (P_2 - \alpha q_2 + t)\{1 - (P_2 - P_1)/(q_2 - q_1)\} \qquad \ldots(34)$$

The Nash equilibrium prices for the two goods in this case are obtained as

$$HF\ :\ P_1 = \{(2\alpha' + \alpha)q_1q_2 - 2q_2 s - tq_1 + q_1(q_2 - q_1)\}/(4q_2 - q_1)$$

$$FF\ :\ P_2 = q_2\{2\alpha q_2 + \alpha' q_1 - 2t - s + 2(q_2 - q_1)\}/(4q_2 - q_1) \qquad \ldots(35)$$

Therefore, we get the equilibrium demands faced by the two firms as

$$HF\ :\ D_1 = q_2\{\alpha q_2 - \alpha'\,(2q_2 - q_1) + (q_2 - q_1) - t + s(2q_2 - q_1)/q_1\}/\{(q_2 - q_1)(4q_2 - q_1)\}$$

HF: $\Pi_1^{RS} = q_1q_2\{(1-\alpha)(q_2-q_1) + (2q_2-q_1)\,\alpha y - t + s(2q_2-q_1)/q_1\}^2/\{(q_2-q_1)(4q_2-q_1)^2\} - C(y)$
FF: $\Pi_2^{RS} = \{(\alpha' + \alpha)q_1q_2 + 2q_2(q_2-q_1) - 2\alpha q_2^2 + (2q_2-q_1)t - q_2 s\}^2/\{(q_2-q_1)(4q_2-q_1)^2\}$.
….(37)

In the second stage, the home firm decides about its optimal level of R&D in the sense that it determines as to what extent the marginal cost be reduced through R&D in order to maximize its ex-post profit. Therefore, the problem of the home firm, in this stage, is

$$\max_{y}\ \Pi_1^{RS} = q_1q_2\{(1-\alpha)(q_2-q_1) + (2q_2-q_1)\,\alpha y - t + s(2q_2-q_1)/q_1\}^2/\{(q_2-q_1)(4q_2-q_1)^2\} - cy^2$$

subject to $0 \le y \le 1$. ….(38)

As the objective function in the above maximization problem is concave in y, while the inequality constraints are convex in y, we solve it by applying Kuhn-Tucker conditions for maximization. Thus solving, we get the optimal level of y, for given levels of s and t, as

$$y^*(s, t) = \alpha q_1q_2(2q_2 - q_1)\{(1-\alpha)(q_2-q_1) - t + s/q_1\}/\{c(q_2-q_1)(4q_2-q_1)^2 - \alpha^2q_1q_2(2q_2-q_1)^2\}. \quad ….(39)$$

As per the definition in (33), $y^*(s, t)$ is always positive for $c > \underline{c}$. From (39), it could be seen that the optimum y increases with s and declines with the increase in t. This implies that the home firm's R&D effort is encouraged by the subsidy programme of the home government but is discouraged by the same of the foreign government.

Now, in the first stage of the game, the government of each of the two exporting countries maximizes its social welfare function with respect to its own subsidy parameter subject to the subsidy reaction function of the other. The social welfare functions of the two exporting countries, i.e. G_1^{RS} and G_2^{RS}, are given below.

HG : $G_1^{RS} = \Pi_1^{RS} - sD_1 - cy^2$
$= q_1q_2[(1-\alpha)(q_2-q_1) + (2q_2-q_1)\,\alpha y - t - 2q_2s/q_1][(1-\alpha)(q_2-q_1) + (2q_2-q_1)\,\alpha y - t + s(2q_2-q_1)/q_1]/\{(q_2-q_1)(4q_2-q_1)^2\} - cy^2$

FG : $G_2^{RS} = \Pi_2^{RS} - tD_2$
$= q_2^2[2(1-\alpha)(q_2-q_1) - \alpha yq_1 - 2t - s][2(1-\alpha)(q_2-q_1) - \alpha yq_1 + (2 - q_1/q_2)t - s]/\{(q_2-q_1)(4q_2-q_1)^2\}$ ……..(40)

Let us now denote

$$m = \delta y/\delta s = \alpha q_2(2q_2 - q_1)/[c(q_2-q_1)(4q_2-q_1)^2 - \alpha^2q_1q_2(2q_2-q_1)^2] \quad …..(41)$$

where m is the marginal impact of export subsidy on the R&D outcome of the home firm. Accordingly, y could be written as

$$y = mq_1\{(1-\alpha)(q_2-q_1) - t + s/q_1\}. \quad …..(42)$$

Solving the first order conditions for maximizing the social welfare functions in (40) above, we get the optimal values of s and t as

HG : $s^* = [(1-\alpha)(q_2-q_1)(2 - \alpha mq_1^2)(4q_2-q_1)v]/[q_2(1+\alpha mq_1)\{2w(\alpha mq_1^2 + 2 - q_1/q_2) - v(2\alpha mq_1^2 - q_1/q_2)\}]$

FG : $t^* = (w - v)(1-\alpha)(q_2-q_1)(2\alpha mq_1^2 - q_1/q_2)/\{2w(\alpha mq_1^2 + 2 - q_1/q_2) - v(2\alpha mq_1^2 - q_1/q_2)\}$
……(43)

where $v = q_2\{\alpha(1-q_1)(2q_2-q_1)m - 1\}/\{(q_2-q_1)(4q_2-q_1)^2\}$
and $w = (2 - \alpha mq_1^2)[q_2(2q_2-q_1)(\alpha mq_1 + 4q_2/q_1)/\{(q_2-q_1)(4q_2-q_1)^2\} + 2cm^2]/(1+\alpha mq_1)$
……(44)

Closer inspection of (44) shows that (w - v) and $\{2w(\alpha mq_1^2 + 2 - q_1/q_2) - v\,(2\alpha mq_1^2 - q_1/q_2)\}$ will have the same sign, except a very few cases, both of them being either positive or negative depending on the values of the basic parameters, i.e., α, q_1, q_2 and c. For higher values of c, both of them are positive. For lower values of c subject to the condition that $c > \underline{c}$, both of the expressions would still be positive except a very few cases. When the values of q_1 and q_2 are very close, i.e. when both the products are almost perfect substitutes, both or either of the above two expressions may be negative in some cases.[3] Therefore, except in few cases, the sign of t^* would largely depend on the sign of $(2\alpha mq_1^2 - q_1/q_2)$. We are now in a position to state the following proposition.

Proposition 4: Given that $m < 1/\{\alpha(1 - q_1)(2q_2 - q_1)\}$, the home government would implement an export tax policy while the foreign government would implement an export subsidy policy if m, the marginal impact of subsidy on R&D outcome, lies in the range of $(1/2\alpha q_1q_2,\ 2/\alpha q_1^2)$.[4]

Proof : Given that $m < 1/\{\alpha(1 - q_1)(2q_2 - q_1)$, from (44) we get $v < 0$.

Again, for $m \in (1/2\alpha q_1q_2,\ 2/\alpha q_1^2)$, from (44) we get $w > 0$, as also

$$\{2w(\alpha mq_1^2 + 2 - q_1/q_2) - v\,(2\alpha mq_1^2 - q_1/q_2)\} > 0.$$

Therefore, it follows from (43) that $s^* < 0$ and $t^* > 0$. Hence the proposition.

The intuition behind such result is that, when the home firm does R&D for process innovation successfully, then the lower cost of production reduces the price charged for the lower quality product thereby making it more competitive in the third country market. As seen from (29), a reduction in α' would result in an increase in D_1^{R*} and a fall in D_2^{R*}. So, the lower cost of production by the home firm would increase the home firm market share in the third country market thereby giving the home government an opportunity to shift some of the profit to the home country by imposing an export tax. As for the foreign country, lower home firm marginal cost would result in a lower demand faced by the foreign firm thereby forcing the foreign government to provide an export subsidy to its firm to maintain its competitiveness. The importance of this result lies in the fact that, the conditions of the result notwithstanding, existence of product differentiation and a R&D cost function with the characteristics of the diminishing return may lead to a different policy prescription than was mentioned in Spencer and Brander (1983). Spencer and Brander (1983) considered homogeneous product duopoly among a foreign firm and a home firm with differing marginal costs. They suggested that it would be optimal for both the governments to provide export subsidies along with imposing R&D tax to their respective firms in order to increase their respective welfare. They considered Cournot competition among the firms and a linear R&D cost function. Eaton and Grossman (1986) considered price competition under homogeneous duopoly and showed that export tax should be the optimal strategic trade policy for both the governments. Here, however, we see that once that homogeneity is relaxed and one of the firms is allowed to reduce its marginal cost through R&D, the strategic trade policy may very well differ from these policy prescriptions. As stated in the following proposition, there could also be cases, where providing export subsidy to their respective firms becomes an optimal strategy of market intervention for both the governments, even under price competition.

Proposition 5: Subject to $c > \underline{c}$, both the governments would subsidize the exports of their respective firms when

either $m > \max\{1/[\alpha(1 - q_1)(2q_2 - q_1)],\ 2/\alpha q_1^2\}$

or $\max\{1/[\alpha(1 - q_1)(2q_2 - q_1)],\ 1/(2\alpha q_1q_2)\} < m < 2/\alpha q_1^2$.

Proof : When $m > \max\{1/[\alpha(1 - q_1)(2q_2 - q_1)],\ 2/\alpha q_1^2\}$, we have $v > 0$ and $w < 0$.

So, $w - v < 0$. Also, we have

But when max $\{1/[\alpha(1 - q_1)(2q_2 - q_1)], 1/(2\alpha q_1 q_2)\} < m < 2/\alpha q_1^2$, we get $v > 0$, $w > 0$.
Also, $w > v$ because $m > 1$ in this case. Hence

$$2w(\alpha m q_1^2 + 2 - q_1/q_2) - v(2\alpha m q_1^2 - q_1/q_2) > 0.$$

Therefore, we get $s^* > 0$ and $t^* > 0$.

Certainly, the conditions above imply that c has to be a very small number, with a lower limit of $\underline{c}$, i.e., the effort level of the R&D group of the home firm has to be very high. This is the case when the marginal impact of export subsidy on the R&D outcome of the home firm is high. So, the export subsidy policy by the home government would help the home firm reduce its marginal cost even further. This would result in a substantial fall in the price charged for the lower quality good, thereby helping the home firm enjoy a higher market in the third country. The foreign government would have no other option but to subsidize the exports of the foreign firm in order to maintain its competitiveness. From (2) we can see that if P_1 falls, then r^* would go up, implying a lower market share for the foreign firm. Therefore, the foreign government has to provide export subsidy to its firm if there is any decline in the price charged for the lower quality good. However, there could be some cases where export taxation becomes the optimal policy for the foreign government even when export subsidization becomes the optimal policy for the home government.

Proposition 6: When $1/[\alpha(1 - q_1)(2q_2 - q_1)] < m < 1/(2\alpha q_1 q_2)$, export taxation is the optimal policy for the foreign government while export subsidization is the optimal policy for the home government.

Proof: When $1/[\alpha(1 - q_1)(2q_2 - q_1)] < m < 1/(2\alpha q_1 q_2)$, we have $v > 0$ and $w > 0$, because $1/(2\alpha q_1 q_2) < 2/(\alpha q_1^2)$. Also we get $w > v$ as $m > 1$.
Moreover, as $m < 1/(2\alpha q_1 q_2)$, we get

$$2w(\alpha m q_1^2 + 2 - q_1/q_2) - v(2\alpha m q_1^2 - q_1/q_2) > 0.$$

Therefore, we get $s^* > 0$ and $t^* < 0$.

In this case, export taxation by the foreign government increases the price of the higher quality good. So, the benefit to the foreign country from such policy comes from higher profit margin rather than a higher market share. On the contrary, the home country draws benefit mostly from higher market share through lowering price of the lower quality good both by reducing the marginal cost of production by doing R&D as also through export subsidization.

CONCLUSION

The homogeneous good duopoly models of the literature prescribe for export subsidization if the competition between the firms is characterised by Cournot competition, and export taxation if it is Bertrand. However, there are theoretical models in this literature which consider product differentiation and also conjectural variation among the firms. But, there is rarely any study that considers R&D by rival firms in a non-homogeneous good duopoly or oligopoly. In the present paper, we consider one such scenario where the rival firms produce goods of two different qualities. In this case, only the home firm is allowed to do R&D for the purpose of reducing its marginal cost of production. The results presented here show that the optimal policy of either of the governments depends crucially on the exogenous variables like the qualities of the two products, the technology level of the production process and also the parameters representing the R&D effort of the home firm.

Considering the cases where both the firms undertake R&D activities can further enrich the very small. In such a scenario, process innovation could be of immense importance. The policy prescriptions in an uncovered market with such characteristics are worth an examination.

ENDNOTES

[1]Espeli (1997) presents the negative aspects of such government intervention as it studies the Norwegian experience. It argues that, since 1890s, the Norwegian textile industry 'seems to have worked more assiduously to gain protection than to adjust and be innovative in relation to changing market conditions and production technology.'

[2] Moore (1990), however, contradicts this hypothesis while examining the strategic trade policy of the Japanese government in the semiconductor industries. Quantifiable R&D and trade policy is considered to argue that the policies have not significantly affected the profitability of three US firms in the industry.

[3] A simulation test showed that $(w - v)$ is negative when $c \leq 1.25$ and $(q_2 - q_1) \leq 0.05$. Of course, this was valid only in very few cases in the simulation test where c was allowed to be halved twenty times from 10, α was allowed to vary from 0.9 to 0.1, q_2 was allowed to vary from 0.3 to 1.0 and q_1 was allowed to vary from 0 to such a value that $(q_2 - q_1) = 0.05$. Only those values of c were considered here for which $c > \underline{c}$.

[4] s^* may also be negative when $2/\alpha q_1^2 < m < 1/\{\alpha(1 - q_1)(2q_2 - q_1)\}$, which is possible only when the values of q_1 and q_2 are very close. In this case $t^* > 0$. This also shows that even when the goods are near substitutes, export taxation by home country and export subsidisation by the foreign country are optimal strategy for intervention in the market by the respective governments. This result is somewhat in contradiction with Eaton and Grossman (1986) who prescribes that for cases where goods are perfect substitutes, export taxation by both the governments are optimal under price competition.

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