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Abstract: We examine, in the context of less developed countries, the R&D behaviour of oligopolistic firms who compete over R&D, as well as output levels. We also assume that the firms can sell in either of the two markets - the domestic, or the foreign. We show that entry liberalization, despite increasing the level of competitiveness, does not affect the level of R&D. An increase in export subsidy may, however, lead to an increase in domestic R&D. Both these results contradict the popular argument that the levels of domestic R&D is positively related to the level of domestic competitiveness. We also demonstrate that any foreign firm that may enter selects a level of R&D that is atleast as efficient as that selected by any domestic firm. Finally, we demonstrate that entry liberalization has a positive effect on exports, as well as aggregate output.

Key words: Entry liberalization, export subsidy, R&D, competitiveness.

JEL Classification No.: F12, O32.

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1 Introduction

In this paper we study the impact of some government policies - namely entry liberalization and export subsidy - on the levels of domestic R&D.

Domestic industries, especially in less developed countries, have often been protected. Such protectionism has been criticised on many grounds in the literature. It has been argued that not only does such protectionism lead to cost inefficiencies, but it also leads to a slower development of new technologies, thus widening the gap between the developed and the developing nations. It is also argued that a reduction in the level of such protectionism would, through an increased level of domestic competition, lead to an increase in the level of domestic R&D. It is the primary goal of this paper to examine the links between the levels of R&D and protectionism in a formal context.

We consider a domestic oligopoly where the firms can sell either in the domestic market, or in the foreign market. Since we are mainly interested in the problems of the less developed countries (LDCs from now on), we assume that the domestic firms are small relative to the world market, i.e. the domestic firms are price takers in the world market. We examine a two stage oligopoly model, where, in the first stage the firms compete on the levels of R&D, and then, in the second stage, they compete in the product market.

Before proceeding with the results let us note that there are some other interesting problems that can be formulated in this framework. The first question examines what is the crucial bottleneck in domestic R&D, incentives, or the access to foreign technology. If, in equilibrium, the domestic firms use their most efficient technology, then we say that there are no incentive problems, it is the access to technology that is the crucial bottleneck. If, on the other hand, the firms use a less than efficient level of R&D, then we say that there is an incentives problem and access to technology is not a

binding constraint.

Our exercise also has some relation to the transfer of technology debate in the Indian literature. While some authors suggest that the foreign firms dump inefficient technologies on their Indian counterparts, others suggest that they sell the vintage that they themselves are currently using.¹ While our model is concerned with the direct entry by the foreign firms themselves, and not with technology transfer per se, we can ask whether these foreign firms will perform R&D at an 'efficient' level or not.

We also examine the impact of entry on exports, as well as on domestic output. Agarwal and Barua (1994), as well as Marjit and Raychaudhuri (1997) demonstrate, in a model that is very similar to our own, that as a result of entry both exports and aggregate output would increase. Their model, however, does not take the R&D stage into account. It is of interest to examine if similar results go through even in the presence of R&D.

We then briefly describe our main results. Interestingly enough, we find that the R&D levels of the firms can be linked to their performance in the product market. For firms that sell in the domestic market alone, the R&D is always chosen at their most efficient level. For firms that sell in both the markets, however, the results are more complex. We find that these firms may or may not choose their most efficient technology. Thus for firms that sell in the domestic market alone there are no incentive problems, the only problem lies in obtaining an access to better technology. For the other firms, however, incentives, as well as access to technology can cause problems.

Surprisingly enough, neither group of firms are affected in their R&D choice by entry liberalization. The intuition for this as follows. For firms that sell in the domestic market alone, competitive pressures ensure that they choose their most efficient level of R&D. With an increase in the number of firms the competitive pressure is even greater, and thus they still select

¹For a survey of this literature we refer the readers to Desai (1985).

their most efficient technology. Hence the result follows. For firms that sell in both the markets the argument is more subtle. In case of those firms that choose their most efficient technology the earlier reasoning applies. For the other firms the reason depends on the way the incentives for R&D alter as entry occurs. It is true that increased entry causes an increased level of competition. However, over the relevant range the shift in the profit of the firm (as a function of the level of R&D) is parallel in nature. Thus there is no change in the relative attractiveness of the various levels of R&D, and hence the result follows.

In the case of export subsidies, however, the results are somewhat different. For the firms that were using a less than efficient level of R&D, the level of R&D increases in response to an increase in the subsidy level. However, the firms that were already using their most efficient technologies will not be affected by the export subsidy. They will still be using their most efficient technologies.

Thus we find that the results in our model run counter to the standard arguments. Entry liberalization, despite increasing the level of domestic competitiveness, has no effects on domestic R&D, while export subsidy, which decreases the level of domestic competition, may increase domestic R&D.

The results on exports and domestic output are, however, more standard. We note that, since entry liberalization does not affect the level of R&D, the Agarwal and Barua (1993) and the Marjit and Raychaudhuri (1997) results apply i.e. aggregate exports, as well as aggregate output increase.

Our results also demonstrate that any possible apprehension regarding the level of R&D choice by foreign firms is unfounded. We show that these firms will use a level of R&D that is at least as efficient as that used by the most efficient domestic firm.

The rest of the paper is organized as follows. Section 2 presents the basic model and develops some preliminary lemmas. Section 3 derives the main

results of this paper. Finally, section 4 concludes.

2 The Model

The model used in this paper is an extension of that used in Agarwal and Barua (1993, 1994) and Marjit and Raychaudhuri (1997). We, however, extend the model by including an R&D phase that precedes competition in the product market.

Consider an industry consisting of N firms that produces a homogeneous good. The firms can sell in either of the two markets - the domestic, or the foreign. We let $f(Q)$ denote the inverse demand function in the domestic market. As discussed in the introduction, foreign demand is assumed to be infinitely elastic at the level p_f . We also assume that the country is protected by a sufficiently high tariff or quota, so that imports are not allowed.²

We then introduce a few notations that we require for the analysis. Let q_d^i and q_f^i denote, for the i th firm, domestic and foreign sales respectively. The total output of the i th firm is denoted by X_i , where $X_i = q_d^i + q_f^i$. We let Q_d represent the aggregate domestic demand, so that $Q_d = \sum_i q_d^i$. The cost function of a typical firm is given by $C_i(X_i)$, where $C_i(X_i) = h_i c(X_i)$, with h_i denoting a cost parameter. In our model h_i is also interpreted as the R&D parameter.

We model the problem as a two stage game where, in the first stage, the firms simultaneously make their R&D choices, and then, in the second stage, they simultaneously decide on the amount to be sold in each market. We begin by modelling the R&D stage. Assume that the R&D choice of the firm is represented by the choice of the parameter h_i from a given interval $[h_i, \infty)$. Thus the lower the choice of h_i , the lower is the production cost and the greater the level of R&D. However, doing R&D is not costless. We

²For less developed countries this assumption, atleast for some industries, maynot be very unreasonable.

assume that the cost of doing R&D is captured by the function $r(h)$.

Thus the profit function of a typical firm is as follows

$$P_i = f(Q_d)q_d^i + p_f q_f^i - h_i c(q_d^i + q_f^i) - r(h_i). \quad (1)$$

Notice, however, that for the second stage game in output, the level of R&D is already given and $r(h_i)$ is now a sunk cost. Thus while analysing the second stage game we can employ the simpler profit function

$$\pi_i = f(Q_d)q_d^i + p_f q_f^i - h_i c(q_d^i + q_f^i). \quad (2)$$

We then impose a few restrictions on the demand function $f(Q_d)$, and on the two cost functions, $h_i c(X_i)$ and $r(h)$.

A.1: The demand function $f(Q)$ is twice continuously differentiable, $f'(Q) < 0$ and $\sup f(Q) > p_f$. Moreover, $f'(Q) + qf''(Q) < 0, \forall q \leq Q$.

A.2: The cost function $C_i(X)$ is twice continuously differentiable, with $hc'(X) > 0$ and $hc''(X) > 0$. Moreover, $hc(0) = 0$ and $hc'(0) = 0$.

Notice that the assumption that $\sup f(Q) > p_f$ implies that it is worthwhile to sell in the domestic market. Otherwise all the firms would sell in the foreign market alone and the problem becomes trivial. The condition that $f'(Q) + qf''(Q) < 0, \forall q \leq Q$ is the well known Hahn condition. Hahn (1962) used this assumption to establish the global stability of Cournot equilibrium. We, however, will use this assumption to ensure that some of our key equations have a unique solution.

As regards assumption A.2 notice that the assumptions $hc(0) = 0$ and $hc'(0) = 0$ together imply that the domestic sales level is always strictly positive, and thus the equilibrium is interior. The rest of the conditions are standard and require little explanation.

A.3: $r(h)$ is twice continuously differentiable, with $r'(h) < 0$ and $r''(h) > 0$.

Thus the R&D costs are assumed to be increasing and convex in the level of R&D, where recall that an increase in h_i signifies a decrease in the level of R&D.

We then use a standard backwards induction argument to solve this game. We begin by considering the second stage game in outputs.

Assume that the first M firms sell in both the domestic and the foreign market, whereas the other firms sell in the domestic market alone. Thus the first order conditions for a Cournot equilibrium can be written as follows:

$$\frac{\partial \pi_i}{\partial q_d^i} = f(Q_d) + q_d^i f'(Q_d) - h_i c'(q_d^i + q_f^i) = 0, \quad i = 1, \dots, M, \quad (3)$$

$$\frac{\partial \pi_i}{\partial q_f^i} = p_f - h_i c'(q_d^i + q_f^i) = 0, \quad i = 1, \dots, M, \quad (4)$$

$$\frac{\partial \pi_j}{\partial q_d^j} = f(Q_d) + q_d^j f'(Q_d) - h_j c'(q_d^j) = 0, \quad j = M + 1, \dots, N. \quad (5)$$

Here observe that equation (4) establishes something that is useful for our future analysis. It states that for firms that sell in both the markets, the total output levels *do not* depend on the domestic demand condition, but on the level of foreign price alone. Thus the cost levels also depend on p_f alone.

It is clear that we can combine equations (3) and (4) to write

$$f(Q_d) + q_d^i f'(Q_d) = p_f, \quad i = 1, \dots, M. \quad (6)$$

Now notice that equations (5) and (6) together constitute the first order conditions for a standard Cournot game where the first M firms have the cost functions $p_f X_i$. Thus the standard proofs for the Cournot game applies. As usual existence and uniqueness of the solution follows from the Hahn condition. Finally, since there are no fixed costs and since $h c'(0) = 0$, the solution is interior as well. We can now summarise the above discussion so as to obtain our first lemma.

Lemma 1. *The equation system (5) and (6) have a unique and interior solution.*

Notice that once the domestic output vector (q_d^1, \dots, q_d^N) is uniquely determined, we can use equation (4) to uniquely solve for the export vector (q_f^1, \dots, q_f^M) as well. Thus lemma 1 implies that the Cournot equilibrium is also unique.

Our next lemma studies the impact of a change in the level of R&D on the output levels of the various firms. We show that if a firm becomes more efficient then the domestic sale of that firm declines, while the domestic sales of all other firms in the economy decline. Furthermore, the aggregate domestic sale increases.

Lemma 2. $\frac{\partial q_d^i}{\partial h_i} \leq 0$, $\sum_j \frac{\partial q_d^j}{\partial h_i} \leq 0$ and $\sum_{j \neq i} \frac{\partial q_d^j}{\partial h_i} \geq 0$.

The proof of this lemma relies on equations (5) and (6) and the Hahn condition. Since the formal proof is of little independent interest we have relegated it to the appendix.

Notice that in equation (5) we are dealing with firms that sell in the domestic market alone, while in equation (6) we deal with firms that sell in both the markets. Lemma 3 below is useful as it shows that the product market behaviour of the firms is related to their levels of R&D. Essentially, efficient firms sell in both the markets, while inefficient firms sell in the domestic market alone, which of course is the result we intuitively expect.

Lemma 3. *Given the vector $(h_1, \dots, h_{i-1}, h_{i+1}, \dots, h_N)$, we can find an \hat{h}_i such that the i th firm sells in both the markets if $h_i \leq \hat{h}_i$, otherwise it sells in the domestic market alone.*

The proof follows from lemma 2 and can be found in the appendix.

In any two-stage model a standard complication is that the decisions taken by the firms in the first stage affects the choices of all the firms in the

next stage. This usually leads to some rather messy calculations. In our model, however, such problems are kept to a minimum as a result of the following lemma. It states that for if the R&D level of a firm is very high, then any further change in the level of R&D does not affect the domestic output of the other firms.

Lemma 4. $\frac{\partial q_d^j}{\partial h_i} = 0, \forall i, j$ and $\forall h_i < \hat{h}_i$.

The proof is simple. Consider the i th firm and assume that $h_i < \hat{h}_i$. Thus, from lemma 3, this firm operates in both the markets. Consequently, a change in h_i does not affect the equation system (5) and (6). Since, from lemma 1, the domestic sales vector is uniquely determined by the equations (5) and (6), the result follows.

Finally, we move over to an analysis of the R&D stage. We begin by introducing one more piece of notation. Let $q(h)$ solve the following equation

$$hc'(q) = p_f. \quad (7)$$

Notice that $\forall h_i < \hat{h}_i$, we can write

$$\begin{aligned} \frac{dP_i}{dh_i} &= f'(Q_d)q_d^i \sum_{j \neq i} \frac{\partial q_d^j}{\partial h_i} \\ &+ [f(Q_d) + q_d^i f'(Q_d) - h_i c'(q(h_i))] \frac{\partial q_d^i}{\partial h_i} \\ &+ [p_f - h_i c'(q(h_i))] \frac{\partial q_f^i}{\partial h_i} \\ &- c(q(h_i)) - r'(h_i) \end{aligned} \quad (8)$$

Now consider the right hand side of the above equation. Notice that from lemma 4 the first term vanishes, while the first order conditions in the second stage game imply that the two terms within the square bracket also vanish. Thus we arrive at the next lemma of this section.

Lemma 5. $\forall h_i < \hat{h}_i, \frac{dP_i}{dh_i} = -c(q(h_i)) - r'(h_i)$.

We need one final assumption before we can proceed with the analysis.

A.4: Assume that the industry consists of a single firm that can select its technology parameter from the interval $(0, \infty)$. Then, at the optimum choice of h , the firm participates in both the domestic and the world market.

Notice that assumption A.4 is the counterpart of the assumption that $\sup f(Q) > p_f$. What the assumption that $\sup f(Q)$ does is to ensure that the domestic market is not too small compared to the world price, p_f . Assumption A.4, on the other hand, ensures that the domestic market is not too large either.

We then provide a more precise formulation of assumption A.4. Let \hat{h} be the R&D level for which that marginal cost function passes through the intersection of p_f and the domestic marginal revenue curve. Clearly, if $h < \hat{h}$, then the monopolist sells in both the markets, otherwise it sells in the domestic market alone. Let $P_M(h)$ denote the profit function of the monopolist where we assume that for all values of h , the domestic sales and exports are chosen optimally. Let $h^* = \operatorname{argmax} P_M(h)$. Clearly, h^* satisfies the equation $-c(q(h)) - r'(h) = 0$. We can now formally restate assumption A.4 as follows

$$h^* > \hat{h}. \quad (9)$$

We then consider the shape of the function $P_M(h)$ in greater detail. Notice that for $h < \hat{h}$,

$$\begin{aligned} \frac{dP_M}{dh} &= [q_d f'(Q) + f(Q_d) - hc'(q_d + q_f)] \frac{\partial q_d}{\partial h} \\ &+ [p_f - hc'(q_d + q_f)] \frac{\partial q_f}{\partial h} - c(q(h)) - r'(h). \end{aligned} \quad (10)$$

We then mimic the argument following equation (8) to claim that $\frac{dP_M}{dh} = -c(q(h)) - r'(h)$.

We then impose some regularity conditions on the expression $-c(q(h)) - r'(h)$:

- (i) The expression $-c(q(h)) - r'(h)$ is decreasing in h ,
- (ii) $\lim_{h \rightarrow \infty} -c(q(h)) - r'(h) < 0$, and
- (iii) $\lim_{h \rightarrow 0} -c(q(h)) - r'(h) > 0$.³

Thus for $h < \hat{h}$ the function $P_M(h)$ is inversely U-shaped, with the maximum occurring at h^* . Moreover, since $\hat{h} > h^*$, it follows from the first regularity condition that $\frac{dP_M}{dh}|_{h=\hat{h}} < 0$. We then examine the shape of the $P_M(h)$ function for $h \geq \hat{h}$. Notice that in this case

$$\frac{dP_M}{dh} = -c(\tilde{q}(h)) - r'(h), \quad (11)$$

where $\tilde{q}(h)$ satisfies $qf'(q) + f(q) = hc'(q)$. Notice that for $h > \hat{h}$, $\tilde{q}(h) > q(h)$, which implies that

$$\frac{dP_M(h)}{dh} = -c(\tilde{q}(h)) - r'(h) < -c(q(h)) - r'(h) < 0. \quad (12)$$

Hence it follows that $P_M(h)$ is an inversely U-shaped function with the maximum at h^* .

We then revert back to the case where the industry consists of more than one firms. Let $P_i(h_i)$ denote the profit level of the i th firm when, in the first stage, the other firms choose their technology levels optimally and the output levels in the second stage satisfies the Cournot conditions.⁴ We demonstrate that the shape of $P_i(h_i)$ is also inversely U-shaped, with

$$h_i^* < \hat{h}_i, \quad (13)$$

where $h_i^* = \operatorname{argmax} P_i(h_i)$. Notice that for $N > 1$, the perceived marginal revenue curve lies to the left of the actual marginal revenue curve, and hence

³Consider the case where the firm participates in the export market alone. Notice that these regularity conditions essentially ensure that the R&D choice of the firm has a unique and interior solution.

⁴Strictly speaking we should adopt a different notation since $P_i(h_i)$ has already been defined in equation (1). However, since there are no chances of any confusion between the two, we prefer to use the notation $P_i(h_i)$ and thus avoid the introduction of additional notations.

it intersects the p_f at a lower level of output. This implies that

$$\hat{h}_i > \hat{h}. \quad (14)$$

Next observe that for $h_i < \hat{h}$,

$$\frac{dP_i}{dh_i} = -c(q(h)) - r'(h), \quad (15)$$

and hence for $h_i < \hat{h}$, $P_i(h_i)$ is parallel to $P_M(h)$. Thus for $h_i < \hat{h}_i$, $P_i(h_i)$ achieves a maximum at h^* . Clearly, this implies that $\frac{dP_i}{dh_i}|_{h_i=\hat{h}_i} < 0$.

The next step is to establish that $\forall h_i > \hat{h}_i$, $\frac{dP_i}{dh_i} < 0$. This would establish that h^* is a global maximum of $P_i(h_i)$, and that $\hat{h}_i > \hat{h} > h^*$, which is the result we are after.

Clearly, for $h_i > \hat{h}_i$, we can mimic the argument following equation (8) to show that

$$\frac{dP_i}{dh_i} = -c(\bar{q}(h)) - r'(h), \quad (16)$$

where $\bar{q}(h)$ gives the optimal domestic sales at the equilibrium level. Clearly, $\bar{q}(h) > q(h)$, and thus

$$\frac{dP_i}{dh_i} = -c(\bar{q}(h)) - r'(h) < -c(q(h)) - r'(h) < 0, \quad (17)$$

which completes the argument.

Summarising the above discussion we obtain the final lemma of this section which is the result we shall use repeatedly in the next section.

Lemma 6. *For all industry size N , and for all firms, the function $P_i(h_i)$ is inversely U-shaped and achieves its maximum at h^* . Moreover, $\hat{h}_i \geq h^*$.*

3 The Comparative Statics Results

In this section we analyze the comparative statics results for entry liberalization, as well as export subsidy. We begin by examining the case of entry liberalization.

Here we look at the following problem. Suppose that there are, to begin with, N firms in the economy, out of which M firms sell in both the markets, while the other firms sell in the domestic market alone. Now suppose that an additional N' firms enter the economy. We are interested in comparing the R&D choices made by the firms under these two cases, as well as the levels of export and aggregate domestic output.

We are finally in a position to address some of the issues that were raised in the introduction. Proposition 1, to follow, is concerned with the first N firms, i.e. those firms that already exist in the industry before entry is allowed. The first two parts of the proposition links the product market behaviour of the existing firms with their R&D decisions. The final part of the proposition demonstrates that entry does not affect the R&D levels of the existing firms.

Proposition 1. *In the pre-entry situation, let the equilibrium R&D level for the i th firm be denoted by \bar{h}_i .*

- (i) *For those firms that sell in the domestic market alone, $\bar{h}_i = \underline{h}_i$.*
- (ii) *For those firms that sell in both the markets, either $\bar{h}_i = \underline{h}_i$, or $\bar{h}_i = h^*$.*
- (iii) *Entry of new firms does not affect the equilibrium R&D levels of the first N firms.*

Proof: (i) From lemma 6 we know that $\hat{h}_i > h^*$. Moreover, since the firms sell in the domestic market alone, $\underline{h}_i \geq \hat{h}_i$. Since, for all $h_i \geq h^*$ $\frac{dP_i}{dh_i} < 0$, the result follows.

(ii) For firms that sell in both the markets $\underline{h}_i < \hat{h}_i$. If $\underline{h}_i \leq h^*$, then $\bar{h}_i = h^*$, otherwise $\bar{h}_i = \underline{h}_i$.

(iii) From the above argument it is clear that the R&D choice of the i th firm depends only on the relative values of h^* and \underline{h}_i . Now notice that \underline{h}_i is exogenously given, and, by lemma 6, entry by new firms does not affect h^* .

Thus the equilibrium R&D choice is not affected. ■

We then consider the outcome for the new entrants. The case of interest is where the new entrants are foreign firms from developed nations. It is sometimes debated if the foreign firms choose an ‘efficient’ level of R&D while entering the market of a less developed country. The way the term efficient is defined is not very clear. We say that the R&D choice by a foreign firm is efficient if the level of R&D is at least as high as that chosen by any domestic firm.⁵ We demonstrate that in this sense the foreign firms do choose efficient levels of R&D.

One of the reasons for arguing that foreign firms may opt for less efficient technologies is that the domestic markets in the less developed countries are likely to be small. This is because, it is argued, the incentive for doing R&D is less. In the context of our model, however, we find that a reduction in the size of the domestic market does not affect the levels of R&D by the foreign firms.

Clearly, in the context of developing countries it is reasonable to assume that the foreign firms have a greater access to technology, i.e. if a typical foreign firm selects its technology parameter h_f from the interval $[\underline{h}_f, \infty)$, then for any such firm $\underline{h}_f \leq \min \{\underline{h}_1, \dots, \underline{h}_N\}$. Under this assumption we can show that the foreign firm will choose a level of R&D that is as efficient as that chosen by any domestic firm.

Proposition 2. *(i) Assume that for a foreign firm $\underline{h}_f \leq \min \{\underline{h}_1, \dots, \underline{h}_N\}$. Then this firm will choose a level of R&D that is as efficient as that chosen by any domestic firm.*

(ii) A reduction in the size of the domestic market has no effect on the R&D choices of the foreign firms.

⁵Clearly, we can also ask if the level of R&D is as efficient as the one the foreign firm would have chosen in its own country. This question, while of interest, is not explored in this paper.

Proof: (i) Clearly, from lemma 6 the equilibrium choice of the foreign firms will be either h^* , or \underline{h}_f . Suppose that the most efficient domestic firm chooses h^* , then by assumption $\underline{h}_f \leq h^*$, and the foreign firm opts for h^* . If the domestic firm chooses \underline{h}_i , then the choice of the foreign firm is either h^* , if it is attainable, or \underline{h}_f , if it is not.

(ii) Notice that h^* does not depend on the domestic demand function in any way. Thus a reduction in domestic demand does not affect h^* , and hence the equilibrium R&D outcomes for these firms are not affected. ■

We then examine the impact of entry on exports and the aggregate output, i.e. aggregate exports plus aggregate domestic output. To begin with notice that in our model entry does not affect the levels of R&D. Thus we are effectively back to the world of Agarwal and Barua (1994) and Marjit and Raychaudhuri (1997). As these authors demonstrate, the Ruffin condition is sufficient to ensure that exports and aggregate output increase.⁶ Since we assume that the Hahn condition applies, and since the Hahn condition implies the Ruffin condition, the results in Agarwal and Barua (1994) go through.

Proposition 3. *As a result of entry export, as well as aggregate output increases.*

The effect on aggregate output is of interest because it is an index of the degree of employment in that industry. It is sometimes argued that as a result of entry the output, and hence the employment level in less developed countries might decline. In the context of our model, however, such fears turn out to be baseless.

However, notice that in our model there are no fixed costs, and thus exit

⁶That aggregate exports will increase follows from Result V in Agarwal and Barua (1994). That aggregate output increases follows from Results IV and V in Agarwal and Barua (1994).

is effectively ruled out. Since one of the main strands in the argument is that entry by foreign firms could lead to the liquidation of some domestic firms, our result is not as strong as it may appear at first glance. Thus all we are claiming is that in the absence of exit by any of the domestic firms, entry by foreign firms has no adverse effect on domestic employment.

Finally, we examine the effects of an increase in export subsidy on the levels of R&D. Notice that the effect of the subsidy is to increase the price that the firms obtain from exporting. Thus, if s denotes the per unit subsidy, and if p^* denotes the pre-subsidy foreign price, then we can define

$$p_f = p^*(1 + s). \quad (18)$$

Clearly, in section 2 we can replace p_f by $p^*(1 + s)$ and all the lemmas in that section go through. Notice that in this case h^* depends on s and thus we can write $h^* = h^*(s)$.

Proposition 4 demonstrates that following an increase in the subsidy, s , the R&D level in the economy may increase.

Proposition 4. *Consider those firms for which the equilibrium R&D level is initially at $h^*(s)$. If there is an increase in the export subsidy, then the R&D levels of these firms will increase.*

Proof: Notice that in this case the first order profit maximizing condition implies that

$$-c(q) - r'(h_i) = 0, \quad (19)$$

where q solves the equation

$$hc'(q) = p^*(1 + s). \quad (20)$$

Clearly, as s increases, q increases. Thus, from the convexity of the $r(h)$ function, $h^*(s)$ decreases. ■

Thus while entry has no effects on domestic R&D, an increase in export subsidy may lead to an increase in domestic R&D.

4 Conclusion

The basic message of this paper is that an increase in the levels of domestic competitiveness need not lead to an increase in the level of R&D. In this context the important thing is the way such an increase affects the *relative* attractiveness of various levels of R&D. As our analysis demonstrates, such a change may leave the relative attractiveness of the various levels of R&D, and thus the equilibrium R&D configuration unaffected.

5 Appendix

Proof of Lemma 2. We begin by showing that $\sum_j \frac{\partial q_d^j}{\partial h_i} \leq 0$. Suppose to the contrary that $\sum_j \frac{\partial q_d^j}{\partial h_i} > 0$. Consider the case where the cost parameter of the i th firm declines from h_i to h'_i . Let the pre- and the post-change domestic sales vector be given by (q_d^1, \dots, q_d^N) and $(q_d^{1'}, \dots, q_d^{N'})$ respectively. Then, since $\sum_j \frac{\partial q_d^j}{\partial h_i} > 0$, it follows that $\sum_j q_d^j < \sum_{j'} q_d^{j'}$. But then equations (5) and (6), together with the Hahn condition implies that $q_d^i > q_d^{i'}$, $\forall i$. But summing over all firms we obtain that $\sum_j q_d^j \geq \sum_{j'} q_d^{j'}$, which is a contradiction.

We then use the fact that $\sum_j \frac{\partial q_d^j}{\partial h_i} \leq 0$, equations (5) and (6) and the Hahn condition to establish that $\forall i$, $\frac{\partial q_d^i}{\partial h_i} \leq 0$ and $\sum_{j \neq i} \frac{\partial q_d^j}{\partial h_i} \geq 0$. ■

Proof of Lemma 3. First consider the case where h_i is such that the i th firm sells in both the markets. Clearly, h_i does not enter equations (5) and (6), and thus a decline in h_i does not affect the domestic sales vector.

We then consider the case where h_i is such that the i th firm operates in the domestic market alone. This is characterized by the condition that $q_d^i f'(Q_d) + f(Q_d) > p_f$. As h_i increases, from lemma 3 we can conclude that Q_d , as well as q_d^i declines. This implies that the strict inequality still holds, i.e. the firm sells in the domestic market alone. ■

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