Antidumping Protection and R&D Investment*

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This version, September 03, 2003

Abstract

In recent years, use of antidumping protection has spread throughout the world. Recent evidence shows that R&D-intensive sectors are often targeted, thereby raising a concern that R&D investment might be negatively affected. This paper investigate this issue in a model of reciprocal dumping, in which firms first engage in cost-reducing R&D and then compete internationally. We find that when one government institutes antidumping law the protected firm decreases R&D investment while the constrained firm increases its level. When the other government also adopts antidumping law, the former decreases and the latter increases R&D investment; however, the R&D level is greater for both firms relative to the level under free trade.

JEL Code: F12, F13
Keywords: international oligopoly, R&D games, technological innovation, antidumping protection, reciprocal dumping

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* Earlier versions of this paper were presented at the Midwest International Group and the Southern Economic Association meetings, Emory, Hitostubashi, and Yokohama National Universities. We thank comments from participants at the sessions and seminars.

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1. Introduction

Recent studies [e.g., Tharakan (1999) and Prusa (2001)] show that during the last decade antidumping protection has spread from a handful of traditional users to nearly sixty nations. For example, the traditional anti-dumpers, namely, the U.S., the E.U., Canada and Australia, launched nearly 90 percent of the world's antidumping investigations in 1990, but by 1997 the corresponding figure had fallen to below 50 percent. Researchers also find that antidumping protection has often targeted R&D-intensive industries such primary metals, chemical, electronics and mechanical engineering sectors [see, e.g., Niels (2000)].[1] These facts give rise to a concern that the proliferation of antidumping protection may reduce worldwide R&D investments and even slow world economic growth. This paper aims to investigate this issue.

More specifically, we examine the relationship between R&D investments and antidumping protection in a model of a two-stage game in which two international firms first invest in cost-reducing R&D and then compete in two national markets. The two-stage model of R&D competition is familiar in the industrial organization literature, for example, in the strand of research initiated by d'Aspremont and Jacquemin (1988). The second-stage game builds on the model of "reciprocal" dumping originally due to Brander and Krugman (1983). While they assumed firms play a quantity-setting game, that setup turns out ill-suited for our

[1] These industries are among the top nine R&D intensive sectors, according to the 2001 report published by the Office of Technology Policy of the U.S. Department of commerce that studied U.S. corporate R&D investment between 1994 and 1999. According to WTO reports, those industries were the top four sectors most targeted by antidumping measures between 1995 and 2001 (see http://www.wto.org/english/tratop_e/adp_e/adp_stattab9_e.htm or http://userwww.service.emory.edu/~kmiyagi/).

purpose because a quantity-setting game may not yield a pure-strategy equilibrium in the presence of antidumping. To get around that difficulty, we follow Anderson, Schmitt and Thisse (1995) and assume that firms play a price-setting game.

We first present the free trade regime in which neither country has antidumping policy in place, and compare that case with two antidumping regimes. In the unilateral antidumping regime, we let only one country institute antidumping policy, mimicking the pre-1990 situation in which antidumping was practiced in a small subset of countries in the world. On the other hand, in the regime of reciprocal antidumping we let the other country adopt antidumping policy, capturing the proliferation of antidumping protection in the world. Comparing these regimes with the free trade case yields some counterintuitive results. We find that antidumping protection instituted in a single country diminishes the protected firm's R&D incentive while raising it for the targeted firm, relative to the free trade levels. This asymmetric change is reversed when antidumping spreads to the other county, as the newly protected firm reduces and the other firm increases R&D investment. Nonetheless, the level of R&D investment is greater relative to that under free trade. Now we briefly review some related works. The literature on dumping is too large to be thoroughly reviewed here. We simply note that the Brander-Krugman (1983) model of reciprocal dumping has stimulated a large literature and that its recent applications to the analysis of antidumping include Anderson et al. (1995), noted earlier, Bian and Gaudet (1997), and Veugelers and Vandenbussche (1999). There is another strand of literature, pioneered by Ethier (1982), that focuses on the possibility of "dumping below unit cost" under uncertainty. Staiger and Wolak (1992), for example, have examined the effect of antidumping under market uncertainty.[2] Yet another line of research, e.g., Eaton and Mirman (1991), has shown that dumping occurs as a signal in the presence of incomplete information. The works that analyze the effect of antidumping include Hartigan (1994) and Miyagiwa and Ohno (2002). None of these works have however addressed the issue with which we are concerned.[3]

The present paper is also a contribution to a strand of literature, originally due to Spencer and Brander (1983), on the effect of various trade policy instruments on R&D in the presence of international oligopoly [for example, see Bagwell and Staiger (1992, 1994) and Miyagiwa and Ohno (1995, 1997, 1999)]. This literature has focused on the relative effect of tariffs and quotas (and VERs), not considering the new set of trade policy instruments such as antidumping law.

The remainder of the paper is organized in five sections. Section 2 presents the benchmark or free trade model. Section 3 analyzes the unilateral antidumping regime, while section 4 does the bilateral antidumping regime. Section 5 concludes the paper.

2. The Benchmark (Free Trade) Model

2.1. Setup

We consider a world consisting of two countries, which we call America and Europe. Each country has one national firm, firm A and firm E, respectively. The firms play a two-stage game, first choosing a level of investment in cost-reducing R&D and then competing in both

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[2] See, e.g., Davies and McGuinness (1984), Hillman and Katz (1986) and Das (1992) for models of cyclical dumping.

[3] There are other models that examine the effect of antidumping policy under exogenous technologies; e.g., Dixit (1988), Reitzes (1993) and Bernhofen (1995).

national markets. As in d'Asprement and Jacquemin (1988), we assume that the R&D environment is deterministic and that in the second stage the firms have constant unit production cost, $c_i \equiv c - k_i$, where k_i is the level of investment in R&D firm i made in the first stage. Following Anderson et al., (1995), we assume that the firms produce differentiated goods and compete in prices.

We let (*) denote the variables pertaining to a firm's export market. Thus, x_i* and p_i* denote firm i's export demand and price while x_i and p_i denote the corresponding variables for domestic sale. Furthermore, we assume demands are linear and symmetric. Thus, by the appropriate choice of units we write firm i's home demand as

$$x_i(p_i, p_j^*) = □ - p_i + □p_j^*,$$

and its export demand as

$$x_i^*(p_j, p_i^*) = □ - p_i^* + □p_j$$

where □ and □ are positive parameters. We assume 0 < □ < 1 so the products are substitutes.

2.2. The second-stage game

In search of the subgame-perfect Nash equilibrium, we first solve the second-stage subgame. In the second stage the unit production costs, $c_i \equiv (c - k_i)$, are pre-determined by the R&D investments in the first stage. To export the merchandise each firm incurs "transport costs" which includes shipping and insurance charges, and taxes and tariffs imposed by the foreign governments. Some transport costs, such as shipping charges, are quoted on the per-unit basis while others such as insurance fees and some taxes are based on the value of the merchandise. To incorporate the both types of transport costs, we assume that a unit transport takes the form $(t + \square c_i)$, where t stands for the "specific" transport cost and $\square$ for the "ad valorem" transport cost based on the unit production cost. We assume transport parameters, t and $\square$, are common to the both firms.

Given this unit transport cost, firm i's second-stage (or operating) profit is written as:

(1) $$\square_i(p_i, p_i^*, p_j, p_j^*; c_i) \equiv [p_i - c_i]x_i(p_i, p_j^*) + [p_i^* - c_i - t - \square c_i]x_i^*(p_j, p_i^*).$$

Each firm maximizes this profit by choosing prices, taking as given its competitor's prices in the two markets. The first-order conditions for firm i are:

(2) $$\square - 2p_i + \square p_j^* + c_i = 0$$

for domestic sales and

(3) $$\square - 2p_i^* + \square p_j + Tc_i + t = 0$$

for exports, where we let

(4) $$T \equiv 1 + \square.$$

Eqs. (2) and (3) define firm i's best-response function in the home and the export market, written $p_i = r_i(p_j^*, c_i)$, and $p_i^* = r_i^*(p_j, T_i c_i + t)$, respectively.

Due to the constant marginal costs, the equilibrium can be obtained by considering each national market separately. That is, we can get the Nash equilibrium $\{\hat{p}_i, \hat{p}_j^*\}$ for firm i's national market by first interchanging subscripts i and j in (3) to get firm j's best-response function in its export market and then solving it and (2) simultaneously:

(4) $$\hat{p}_i = \frac{1}{4-\square^2}[\square(2 + \square) + 2(c_i + t) + \square T_j c_j],$$

$$\hat{p}_j^* = \frac{1}{4-\square^2}[\square(2 + \square) + 2(Tc_j + t) + \square c_i],$$

where we let (^) denote the equilibrium value under free trade.

The dumping margin is calculated based on the difference between the *ex-factory* export and home price of the product, that is, the theoretical price of the product as it leaves the factory. This means that the dumping margin calculation is based on the difference between the home and export price *before* freight, insurance, tariffs and taxes, and other costs are included in the price of the product [see Blonigen and Haynes (2002) for details]. Therefore, the dumping margin is defined as:

$$\square_i \equiv (p_i - c_i) - (p_i^* - Tc_i - t).$$

It is easy to check that $\hat{\square}_i > 0$ for each firm, implying the firms dump in each other's home market.

We express firm i's equilibrium (maximum) profit as a function of R&D levels via the identity $c_i \equiv c - k_i$:

(5) $$\hat{\square}_i(k_i, k_j) \equiv [\hat{p}_i(c_i, c_j) - c_i]\hat{x}_i(c_i, c_j) + [\hat{p}_i^*(c_i, c_j) - t - T_i c_i]\hat{x}_i^*(c_i, c_j)$$

where the equilibrium output levels are

$$\hat{x}_i(k_i, k_j) = \frac{1}{4\square\square^2}[\square(2 + \square) - (2 - \square^2)c_i + \square(t + Tc_j)]$$

$$\hat{x}_i^*(k_i, k_j) = \frac{1}{4\square\square^2}[\square(2 + \square) - (2 - \square^2)(t + Tc_i) + \square c_j].$$

2.3. The first-stage (R&D) game

In the first stage the firms simultaneously choose R&D levels, k_i, to maximize overall profit:

$$\Pi_i \equiv \hat{\pi}_i(k_i, k_j) - \gamma k_i^2/2$$

where the second term on the right is the quadratic R&D cost taken from d'Aspremont and Jacquemin (1988).[4] Differentiating the equilibrium-value operating profit $\hat{\pi}_i(k_i, k_j)$ with respect to k_i, we obtain firm i's marginal benefit of R&D:

$$(6) \qquad \partial\hat{\pi}_i/\partial k_i = \frac{\partial \pi_i}{\partial k_i} + \left(\frac{\partial \pi_i}{\partial p_j}\frac{\partial \hat{p}_j}{\partial k_i} + \frac{\partial \pi_i}{\partial p_j^*}\frac{\partial \hat{p}_j^*}{\partial k_i} \right).$$

In (6), notation $\partial\hat{\pi}_i/\partial k_i$ denotes differentiation with only k_j held constant (total differentiation except for k_j) while $\partial\pi_i/\partial z$ denotes differentiation with respect to z with all other variables held constant, all evaluated at given k_i and k_j. For example, $\partial\pi_i/\partial k_i$ thus represents the direct cost-reducing effect of a change in k_i, while all prices and k_j held constant, and is expressed as:

$$\frac{\partial \pi_i}{\partial k_i} = \hat{x}_i(k_i, k_j) + T\hat{x}_i^*(k_i, k_j) > 0$$

using (5).

On the other hand, the second term on the right-hand side of (6) represents the change in firm i's profit induced by the competitor' price changes in response to firm i's R&D investment change, and is called the competition effect. This effect is negative because a decrease in the unit cost due to R&D causes the competitor to reduce its prices, which hurt the firm's profit. We confirm this below.

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[4] We assume that $\gamma > 0$ and is large enough so that $k_i < c$.

$$\frac{\partial \Box_i \Box}{\partial p_j}\frac{\partial \hat{p}_j \Box}{\partial k_i} + \frac{\partial \Box_i \Box}{\partial p_j^*}\frac{\partial \hat{p}_j^* \Box}{\partial k_i} = -\frac{\Box^2}{4\Box\Box\Box^2}\{\hat{x}_i(k_i, k_j) + T\hat{x}_i^*(k_i, k_j)\} < 0.$$

At the optimum, the marginal value of R&D equals the marginal cost of R&D:

(7) $$\partial \hat{\Box}_i/\partial k_i - \Box k_i = \frac{4\Box\Box 2\Box^2}{4\Box\Box\Box^2}\{\hat{x}_i(k_i, k_j) + T\hat{x}_i^*(k_i, k_j)\} - \Box k_i = 0.$$

Provided that $\Box$ is large enough to satisfy the second-order condition, (8) defines firm i's best-response function in the first-stage game, which we write $k_i = \hat{R}_i(k_j)$. It is easy to check that it is downward sloping: $\hat{R}_i'(k_j) < 0$, or R&D efforts are strategic substitutes. Intuitively, R&D investments are strategic substitutes because they are considered sunk in the second stage and hence an increase in R&D investment by one firm reduces the other's operating profit and marginal benefit of R&D, which prompts the other firm to curtail its R&D investment. We denote the equilibrium R&D investment levels by $(\hat{k}_A, \hat{k}_E)$. Under symmetry we have that $\hat{k}_A = \hat{k}_E$.

Finally, we assumed that part of transport cost is based on the unit production cost. Yet, some transport cost may be based on the export price instead of the unit production cost. In this case, the profit from exports in (1) may be written as $[p_i^*/z - c_i - t]x_i^*(p_j, p_i^*)$ with $z > 1$, where now p_i denotes the consumer price while p_i^*/z is the price net of the transport cost to firm i. Multiplying through z however, we obtain $[p_i^* - zc_i - zt]x_i^*(p_j, p_i^*)$. With the appropriate re-labeling of the letters, this is the same definition of the export profit as the original in (1). Thus, our analysis subsumes the case of the price-based transport cost.

3. Unilateral Antidumping

We now proceed to the analysis of antidumping protection. We assume transport costs are low enough for the firms to keep exporting in the presence of antidumping protection. In the benchmark case, we found that both firms dumped into each other's home market. GATT/WTO rules permit the government to levy the import duty at a rate up to the dumping margin against a foreign firm violating the nation's antidumping law. If the maximum duty is levied, the foreign firm faces two options in the present context: pay the duties or eliminate the dumping margin. The next lemma says that the firm always chooses the second option. The intuition is that since either option ends up eliminating the dumping margin the foreign firm is better off avoiding paying duties.

Lemma 1: A firm facing antidumping protection always prefers to eliminate the dumping margin rather than pay the penalties mandated by WTO rules. (Proof is Appendix A.)

With these preparatory remarks, the remainder of this section investigates the effect of unilateral antidumping; that is, when only one country institutes antidumping policy. Without loss of generality we assume it is the American government that imposes antidumping law.

3.1. The second-stage game

By assumption antidumping policy in America imposes the following antidumping (AD) constraint on firm E:

(8) $$\square_E(p_E,\, p_E^*) \equiv (p_E - c_E) - (p_E^* - t - Tc_E\,) \;\square\; 0.$$

Maximizing the operating profit (1) subject to this constraint yields the first-order conditions:

(9) $$\partial\square_E/\partial p_E - \square = 0, \text{ and } \partial\square_E/\partial p_E^* + \square = 0,$$

where $\square$ denotes the multiplier associated with constraint (8). Since constraint (8) is binding at the optimum, the multiplier $\square$ is positive and hence

(10) $$\partial\square_E/\partial p_E > 0 > \partial\square_E/\partial p_E^*.$$

(10) says that, given firm A's prices, firm E is forced to raise the export price relative to the home market price to satisfy the AD constraint. (9) also leads to

(11) $$\partial\square_E/\partial p_E + \partial\square_E/\partial p_E^* = 0.$$

(11) and (8) with strict equality implicitly define firm E's best-response prices, which now depend simultaneously on firm A's export price and home market price.

On the other hand, with no antidumping law against it, firm A behaves the same as in the free trade regime. Its best-response functions are the same as in the free trade regime. Solving these best-response functions simultaneously, we find the Nash equilibrium $\{\tilde{p}_E, \tilde{p}_E^*, \tilde{p}_A, \tilde{p}_A^*\}$ where (~) denotes the equilibrium under unilateral antidumping. These equilibrium prices and corresponding output levels are reported in Appendix B. Comparing them with those in the benchmark leads to:

Proposition 1: Suppose that, starting from free trade, only one government imposes antidumping law. Then, for given k_i's:

(i) each firm raises the price in the market protected by antidumping law and lowers the price in the unprotected market;

(ii) each firm exports less and sells more in the home market; and

(iii) the protected firm earns a greater operating profit while the constrained firm earns less.

These results are just an extension of those of Anderson et al. (1995) to the case with asymmetric production costs. When the American government imposes antidumping law, firm E's best-response price function shifts out in America and shifts inwards in Europe to eliminate the dumping margin as implied by (8). Since firm A's best-response functions are not affected, the shifting of firm E's best-response function raises both firms' prices in America and lowers them in Europe. This explains parts (i) and (ii). For part (iii), firm E evidently is hurt by having to satisfy the antidumping constraint. For firm A, as firm E's best-response function shifts out in America, firm A's price rises less than firm E's due to the Hahn stability conditions; therefore firm A ends up stealing consumers from firm E. With the price and sale up, firm A's profit increases in America. Although firm A's profit falls in Europe by the similar reasoning applied in reverse, this loss is smaller than the gain in its home market because its export share is smaller.

3.2. R&D competition

We now move to the first stage. Since the second-stage game equilibrium outcome is not symmetric, we consider the two firms separately. Begin with firm E, a firm constrained by antidumping protection in America. Let $\tilde{\pi}_E(k_E, k_A)$ be firm E’s maximum operating profit under unilateral antidumping law at arbitrary R&D levels:

$$\tilde{\pi}_i(k_i, k_j) \equiv [\tilde{p}_i(c_i, c_j) - c_i]\tilde{x}_i(c_i, c_j) + [\tilde{p}_i^*(c_i, c_j) - t - T_i c_i]\tilde{x}_i^*(c_i, c_j).$$

Firm E’s marginal benefit of R&D is:

$$\text{(12)} \qquad \frac{d\tilde{\pi}_E(k_A, k_E)}{dk_E} = \frac{\partial \pi_E}{\partial k_E} + \{(\partial \pi_E/\partial p_A)(\partial \tilde{p}_A/\partial k_E) + (\partial \pi_E/\partial p_A^*)(\partial \tilde{p}_A^*/\partial k_E)\}$$

$$+ \{(\partial \pi_E/\partial p_E)(\partial \tilde{p}_E/\partial k_E) + (\partial \pi_E/\partial p_E^*)(\partial \tilde{p}_E^*/\partial k_E)\}.$$

We have already seen the first two terms on the right-hand side; they are the cost-reduction and the competition effect. The third term captures the effect operating through firm E’s own price changes. This effect was nil in the free trade regime but not so here due to the antidumping constraint.

To examine the last effect, we first rewrite it, using (9), as

$$\text{(13)} \qquad (\partial \pi_E/\partial p_E)\{(\partial \tilde{p}_E/\partial k_E) - (\partial \tilde{p}_E^*/\partial k_E)\}.$$

The first derivative is positive. To evaluate the second term, we differentiate the binding constraint (8) with respect to k_E and, recalling the identity $c_E = c - k_E$, we get:

$$\text{(14)} \qquad (\partial \tilde{p}_E/\partial k_E) - (\partial \tilde{p}_E^*/\partial k_E) = (T - 1).$$

Since $T > 1$, (13) is positive. For the intuition, we rewrite constraint (9) as

$$p_E^* - p_E \geq t + (T - 1)c_E.$$

This inequality shows that a lower unit production cost slackens the AD constraint, giving firm E extra room to maneuver its prices to increase profit. Thus, antidumping protection by America gives firm E an additional incentive to invest in R&D.

As for the other two effects, straightforward algebra shows that the cost-reduction effect is smaller under unilateral antidumping than under free trade;

(15) $$(\tilde{x}_E + T\tilde{x}_E^*) < (\hat{x}_E + T\hat{x}_E^*) \qquad \text{(for } T > 1 \text{ or } \square > 0\text{)}.$$

The intuition is that because of the transport cost a unit cost reduction translates into a greater cost saving for exports than for domestic sales but exports are smaller under unilateral antidumping by proposition 1. Thus, this effect is diminished. As for the competition effect, we obtain the difference:

(16) $$-\{\square^2/(4 - \square^2)\}\{(1 + \square/2)(\tilde{x}_E + \tilde{x}_E^*) - (\hat{x}_E + T\hat{x}_E^*)\}$$

$$= -\{(\square/2)\square^2/(4 - \square^2)^2\}\{(2 + \square - \square^2)t + \square(2 - \square^2)c_E + \square\square c_A\} < 0.$$

implying that unilateral antidumping strengthens the competition effect, which is bad for firm E. The intuition is as follows. As we already argued, firm E's unit cost reduction causes its price best-price response function to shift down more in its export market than in the local market, due to the transport cost. As a consequence, firm A lowers p_A more than p_A^*, causing firm E's exports x_E^* to fall more than local sales, x_E. However, firm E's profit margin in exports is increased due to antidumping law, so the fall in exports hurts firm E more than under free trade. Its home sales do not decline as much as under free trade, true, but since its profit margin has dwindled under antidumping, the loss in export profits dominates, thereby reducing firm E's incentive to invest in R&D.

Although both the cost-reduction and the competition effect tend to lower the incentive to invest in R&D, these changes are dominated by the antidumping effect discussed earlier. This is seen by directly comparing the marginal benefit of R&D in the two regimes as follows:

$$\frac{\square\tilde{\square}_E(k_A,k_E)\square}{\partial k_E} - \frac{\square\hat{\square}_E(k_A,k_E)\square}{\partial k_E}$$

$$= \{\square(2 - \square^2)/(4 - \square^2)^2\}\{(2 + \square - \square^2)t + \square(2 - \square^2)c_E + \square\square c_A\} > 0.$$

This means that $\tilde{R}_E(k_A) > \hat{R}_E(k_A)$ or firm E's first-stage game best-response function shifts out due to the institution of antidumping law in America.

Firm A, on the other hand, faces the same unconstrained optimization problem as in section 2.The first-order condition:

$$\frac{\square\tilde{\square}_A(k_A,k_E)\square}{\square k_A} - \square k_A = 0$$

implicitly defines firm A's best response function, denoted by $k_A = \tilde{R}_A(k_E)$ provided that $\square$ is not too large. The marginal benefit of R&D is expressed as

$$\frac{\square\tilde{\square}_A(k_A,k_E)\square}{\square k_A} = (\tilde{x}_A + T\tilde{x}_A^*) - \{(1 + \square/2)\square^2/(4 - \square^2)\}(\tilde{x}_A + T\tilde{x}_A^*).$$

Both the cost-reduction and the competition effect take the same form as those for firm E, and the intuitions developed for firm E applies to firm A. Straightforward calculation shows indeed that the combined effect is smaller under unilateral antidumping. Unlike firm E, however, firm A does not have the antidumping effect that can countervail this diminished incentive. Thus, firm A's best R&D response function shifts inwards.

We illustrate the above discussion in figure 1. Adoption of antidumping policy in America causes firm A's best-response function to shift in from $\hat{R}_A$ to $\tilde{R}_A$ and firm E's to shift outward from $\hat{R}_E$ to $\tilde{R}_E$. Comparison of the equilibrium under free trade at point 1 with that under unilateral antidumping at point 2 immediately yields this next proposition.

Proposition 2: Unilateral adoption of antidumping law by one country decreases R&D efforts by that country's home firm and increases those by its foreign firm.

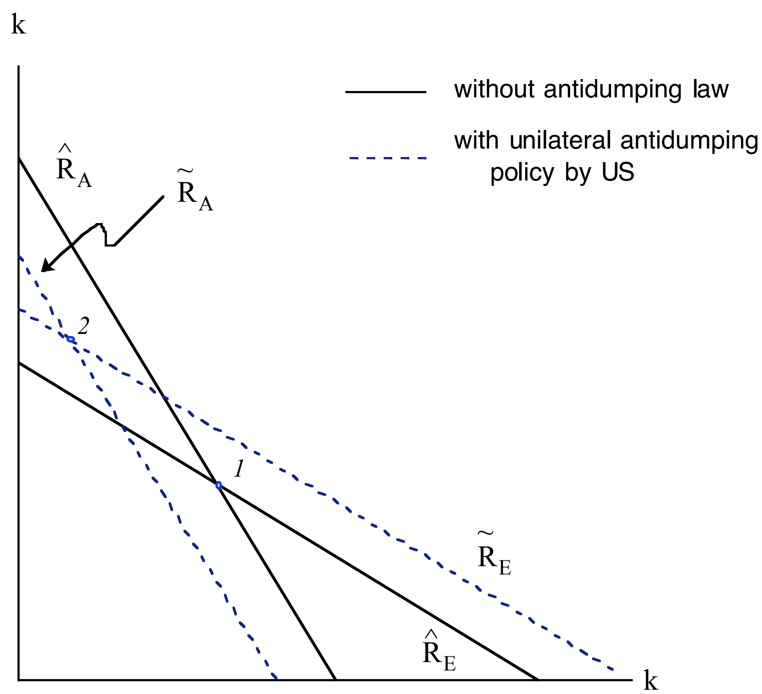

Figure 1: *The effect of unilateral antidumping law by America*

Finally, we note however that the above analysis depends crucially on the assumption that □ is positive (or T exceeds unity). If □ = 0, the antidumping effect vanishes (see (14)), and at the same time neither the cost-reduction effect nor the competition effect is affected by antidumping law because then the total output level does not change (see (15) and (16)). Thus, each firm's best-response function stays put where it is under free trade, meaning that antidumping protection has no effect on R&D investment.

4. Bilateral Antidumping Protection

Now suppose antidumping protection spreads throughout the world (to Europe in this small world of ours). In the second-stage game, since both firms are subject to the dumping constraint, each has really one price to set freely. Substituting the dumping constraint $(p_i - c_i) - (p_i^* - c_i - T) = 0$, we write firm i's combined profits from the two markets in terms of its home market price as follows:

$$□_i = (p_i - c_i)(x_i + x_i^*).$$

Similarly, we can write firm j's combined profits in terms of its export price as

$$□_j = (p_j^* - t - Tc_j)(x_j + x_j^*).$$

Maximizing these yields two best response functions $p_i = r_i(p_j^*, c_i, c_j)$ and $p_j^* = r_j^*(p_i, c_i, c_j)$, which can be solved for a pair of prices in firm i's home market. The equilibrium prices in firm j's home market are obtained by interchanging the subscript. These equilibrium prices and associated output levels are reported in Appendix C.

It is straightforward to show the following results.

Proposition 3: For given k_A and k_E, suppose that the both governments institute antidumping protection. Then, relative to the free trade regime, both firms

(i) charge lower prices in the home market and high prices in the export market;

(ii) export less and sell more in the home market; and

(iii) make smaller operating profits.

This is again a slight generalization of the result in Anderson et al. (1995).

We now define a firm's overall profit: $\bar{\square}_i(k_i,k_j)$ - $\square k_i^2/2$, where $\bar{\square}_i(k_i,k_j)$ is the maximum (equilibrium) operating profit under the bilateral antidumping regime. Each firm faces the same constrained optimization problem as firm E did in the unilateral antidumping regime. A procedure similar to the one used there goes to show that neither firm's marginal benefit of R&D is increased relative that in the benchmark case, causing the both firms' best-response function to shift out. The following result is an immediate consequence.

Proposition 4: Suppose both countries institute antidumping policy. In the symmetric equilibrium each firm invests more in R&D than it does under free trade.

Evidently, propositions 2 and 4 indicate that $\bar{k}_A > \tilde{k}_A$ and $\bar{k}_E < \tilde{k}_E$. So,

Proposition 5: When both American and Europe institute antidumping policy, firm E (firm A) invests less (more) in R&D than when only America alone institutes antidumping law.

Now, firm E faces the same constrained optimization problem in the two AD regimes. Let $\bar{\square}_E(k_A)$ denote firm E's maximum overall profit from the game in which firm E chooses k_E at given k_A and then plays a price-setting game with firm A. That is

$$\bar{\square}_E(k_A) = \{[\bar{p}_E(k_A) - [c - \bar{k}_E(k_A)]\}[\bar{x}_E(k_A) + \bar{x}_E^*(k_A)] - \square[\bar{k}_E(k_A)]^2/2.$$

This measures firm E's overall profit on the best-response function $\tilde{R}_E(k_A)$ under the AD constraint; that is, for both the unilateral and bilateral antidumping regimes. The two regimes differ only in k_A. Differentiating this with respect to k_A gives

$$\bar{\square}_E'(k_A) = [\bar{p}_E - (c - \bar{k}_E)]\partial(\bar{x}_E + \bar{x}_E^*)/\partial k_A < 0$$

The inequality follows because

(17) $$\partial(\bar{x}_E + \bar{x}_E^*)/\partial k_A = -\square(2 + \square)/(4 - \square^2) < 0$$

(see Appendix C). Thus, an increase in k_A reduces firm E's profit along the best-response function $\tilde{R}_E(k_A)$. Since $\bar{k}_A > \tilde{k}_A$ we have $\bar{\square}_E < \tilde{\square}_E$. Firm E thus is hurt if Europe follows suit and institutes antidumping protection of its own in response to American antidumping policy. As for firm A, the impact on its overall profit of going from unilateral to bilateral antidumping is ambiguous. On the one hand, having to satisfy Europe's antidumping constraint decreases its profit but the subsequent decrease in R&D investment by firm E benefits firm A.

5. Concluding Remarks

This paper examined the effect of antidumping protection on the incentive to invest in R&D within a model of a two-stage game, where firms first invest in cost-reducing R&D and then compete in prices. In the benchmark (free trade) case firms dump into each other's home market due to the presence of transport cost. We compared this benchmark case with two antidumping regimes. The main conclusion is that unilateral antidumping policy causes the protected firm to reduce R&D investment and the constrained firm to raise its R&D level, while bilateral antidumping reverses this outcome only partially so that both firms end up investing more in R&D relative to the R&D level under free trade.

It is dangerous to draw any policy implications from any stylized models like ours. However, the present analysis implies that the government that protects the 'home" firm unilaterally with antidumping policy may run the risk of losing its technological edge to its competitor in the long run. This result is consistent with the conventional wisdom that argues protection leads to indolence. Our model also suggests that the spread of antidumping policy in recent years need not depress R&D incentives after all relative to free trade.

Needless to say, the robustness of our results need to be checked in other models under alternative assumptions. First, we utilized a simple deterministic R&D process. One can easily extend the model to a stochastic R&D and dynamic setting, for example, by adopting the framework developed by Lee and Wilde (1980). This extension is unlikely to reverse our conclusion. Second, our results is probably sensitive to the way dumping is modeled. We need to re-examine the issue raised in this paper in alternative models of dumping, some of which were mentioned in the introduction of this paper. Third, the model has ignored the intertemporal aspects of actual antidumping policy. In the real world, when a firm is found guilty of dumping, the duties are imposed on its future exports. This gives rise to the possibility that a firm dumps and pays duties later. It seems a useful exercise to extend our model to examine this case because firms may not eliminate dumping altogether. Finally, our model was in a partial-equilibrium framework. It would be an important extension to examine the issue within a general-equilibrium model, in particular, in the context of economic growth. We leave these extensions for future research.

Appendix

Appendix A: Proof of Lemma 1

The proof is by contradiction. Suppose that firm i is subject to the dumping constraint and in the equilibrium chooses {p', p^{*}'} such that □' is positive (firm index i is suppressed). Due to a positive dumping margin, the firm pays the penalty □'x^{*}' under WTO rules, where x^{*}' is the amount of exports corresponding to the export price, p^{*}'. The firm's export revenue, net of the penalty, is (p^{*}' - □')x^{*}'. By setting the export price equal to p^{*}'' = p^{*}' - □', however, the firm can comply with antidumping law, avoid paying the penalty and yet collect the same revenue p^{*}''x^{*} = (p^{*}' - □')x^{*}'. However, since p^{*}'' < p^{*}', the corresponding export demand x_i^{*}'' > x_i^{*}. Therefore, the firm can receive more revenue by complying with antidumping law, which contradicts the initial assumption that {p', p^{*}'} are the equilibrium prices. ■

Appendix B: Equilibrium in unilateral antidumping

Let M ≡ {4(4 - $\square^2$}. The equilibrium prices are as follows:

$$\tilde{p}_E = \{2(2 + \square)(2\square - t + \square t) + 2(4 - 2\square + \square^2\square)c_E + 2\square(2 + \square)c_A\}/M.$$

$$\tilde{p}^{*}_E = \{2(2 + \square)(2\square + 3t - \square t) + 2(4 + 6\square - \square^2\square)c_E + 2\square(2 + \square)c_A\}/M.$$

$$\tilde{p}_A = \{(2 + \square)(4\square + 3\square t - \square^2 t) + (8 + \square^2\square)c_A + \square(4 + 6\square - \square^2\square)c_E\}/M$$

$$\tilde{p}_A{*} = \{(2 + \square)(4\square + 4t - 3\square + \square^2 t) + (8 + 8\square - \square^2\square)c_A + \square(4 \square 2\square + \square^2\square)c_E\}/M$$

The equilibrium output levels are

$$\tilde{x}_E = \{(2 + \square)[4\square + t(2 + 2\square \square 3\square^2 + \square^3)] - (2 - \square^2)(4 - 2\square + \square^2\square)c_E$$

$$+ \square(4 + 6\square - \square^2\square)c_A \}/M$$

$$\tilde{x}^*_E = \{(2 + \square)[4\square - t(6 - 2\square \square 3\square^2 + \square^3)] - (2 - \square^2)(4 + 6\square - \square^2\square)c_E$$

$$+ \square(4 \square 2\square + \square^2\square)c_A\}/M$$

$$\tilde{x}_A = \{(2 + \square)[4\square + 3\square t \square \square^2 t)] - (8 - 2\square^2 - \square^2\square)c_A + \square(4 + 6\square - \square^2\square)c_E \}/M$$

$$\tilde{x}^*_A = \{(2 + \square)[4\square - 4t + \square t + \square^2 t)] - (8 + 8\square - 4\square^2 - 3\square^2\square)c_A$$

$$+ \square(4 \square 2\square + \square^2\square)c_E\}/M$$

Appendix C: The equilibrium under bilateral antidumping

Let $N \equiv \{2(4 - \square^2\}$. The equilibrium prices are as follows:

$$\bar{p}_i = \{(2 + \square)(2\square - t + \square t) + (4 - 2\square + \square^2\square)c_i + \square(2 + \square)c_j\}/N.$$

$$\bar{p}^*_i = \{(2 + \square)(2\square + 3t - \square t) + (4 + 6\square - \square^2\square)c_i + \square(2 + \square)c_j\}/N.$$

The equilibrium output levels are

$$\bar{x}_i = \{(2 + \square)[2\square + t(1 + 2\square \square \square^2)] - 2(2 - \square^2 - \square)c_i + \square(2 + 5\square - \square^2\square)c_j\}/N$$

$$\bar{x}^*_i = \{(2 + \square)[2\square - t(3 - \square^2)] - 2(2 - \square^2 + 3\square - \square^2\square)c_i + \square(2 \square 3\square + \square^2\square)c_j\}/N.$$

Differentiating we get (17) in the text:

$$\partial(\bar{x}_E + \bar{x}^*_E)/\partial k_A = - \square(2 + \square)/(4 - \square^2) < 0.$$

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