

# Trade Policy and Innovation

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## Abstract<sup>1</sup>

This paper develops a model where firms across countries differ in their capacity to innovate. Our main goal is to study firm level innovation under various trade policy shocks. We consider two countries where firms across countries are heterogeneous in their innovation efficiencies. We find that the benefits of trade liberalization and trade protection differ across firms. One of the main results we obtain is that trade protection hurts the productivity of highly efficient firms while it increases the productivity of lowly efficient firms. The predictions of our model are in line with recent empirical evidence that while trade protection fosters the productivity of lowly efficient firms, it reduces productivity of highly efficient firms.

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## 1. Introduction

A recent worry amongst countries like the US and the EU is how the increased trade competition with countries like China is going to affect the incentives for firms to engage in R&D and other productivity improving investments. Increasingly countries like the EU and US turn to the use of trade protection such as Antidumping measures (AD) to protect industry specific factors in certain sectors. A recent phenomenon is that developing countries have also started to apply contingent protection which has resulted in a recent increase of bilateral trade protection mostly in the form of antidumping duties (Vandenbussche and Zanardi, 2008).

While the model of monopolistic competition, increasing returns and firm heterogeneity has become one of the workhorse models in international trade, it is less suited to study issues of trade policy. The main reason is that its analysis in this setting is complex for unilateral trade policy let alone for bilateral trade policy as shown by Demidova and Rodriguez-Clare (2007) that consider the unilateral case.

In order to study the effects of bilateral trade protection on innovation, we turn to a very different type of model that does not consider firm heterogeneity within countries as in Melitz (2003), but that does allow for heterogeneity across countries. The model's focus is on the analysis of strategic interactions between firms when productivity is decided endogenously rather than drawn randomly. For this purpose we augment the reciprocal dumping model (Brander & Krugman, (1983); Schmitt, Anderson and Thisse (1995)) with a standard IO model on innovation (d'Aspremont & Jacquemin, 1988). In the first period firms can invest in productivity improvements and in the second period firms produce and sell differentiated products and compete in prices. Firms in this model sell both domestically and export abroad. First we consider how unilateral trade protection by a domestic country affects the incentives of domestic firm and foreign firm to innovate. Second we study innovation incentives when the foreign country follows suit and bilateral protection is in place.

Our results show that firm-level responses to unilateral and bilateral trade policy differs depending on firms' efficiency in innovation. Unilateral protection hurts the productivity of highly efficient domestic firms while it increases the productivity of

lowly efficient domestic firms. High versus low productivity are defined in terms of cost of innovation. Bilateral protection reduces domestic R&D to a level that is lower compared to a situation where neither country takes protection. More in particular when one country uses trade policy to increase R&D, retaliation by a second country will lower R&D in the domestic country to a level that is lower than if it had never engaged in protection to begin with.

The endogenization of productivity has been the subject of many studies in industrial economics. Therefore our findings can also be related to some recent papers in that field like Boone (2000) and Aghion et al. (2005). Both have shown that a firm's response to competition depends on its efficiency level. For instance, Aghion et al. (2005) show both theoretically and empirically that an increase in product market competition reduces innovation incentives for laggards.

In previous literature on innovation and trade protection, the maintained assumption was that firms in the model were symmetric (Gao & Miyagiwa, 2005) (G-M). In the absence of heterogeneous firms, G-M show that firm-level R&D investments across countries are always strategic substitutes. Our model extends G-M by introducing heterogeneity in innovation efficiency across countries and has a broader set of predictions. We find that R&D investments can either be strategic substitutes or strategic complements depending on firms' ability to innovate. G-M find that unilateral trade protection always lowers the incentive of the protected firm to innovate, and bilateral protection always spurs firm-level R&D of firms in both countries compared to free trade. Our model encompasses the results of G-M but at the same time we obtain various possibilities for the effects of trade policy on firm-level R&D investment. More specifically, our findings show that while unilateral trade protection spurs innovation of lowly efficient firms, it reduces innovation of highly efficient firms. When protection of lowly efficient firms by one country results in retaliation by another country, the net effect on the first country's firm-level R&D is always negative.

Our theoretical findings correspond well with recent empirical findings of Konings and Vandebussche (2007). Empirically they show that the effects of antidumping protection on productivity of firms depend on firms' initial productivity. They find that "frontier" firms with a high initial productivity lower their productivity

during trade protection while “laggard” firms with a low initial productivity firms increase productivity during protection.

Another way to interpret our results is to think of a lowly efficient innovator as a firm in a developing country and a highly efficient innovator as a firm in a developed country. Recent empirical evidence has shown that in certain sectors notably “Apparel, textiles” and “Footwear”, a number of countries notably China have closed the productivity gap with countries like the EU and the US (Fadinger and Fleiss, 2008). This observation is in line with the predictions of our model that suggests that in sectors where developed countries have lost their edge in innovation there exists an incentive to protect domestic industries. Our model also yields insights that are in line with the predictions by Acemoglu et al. (2003). They find that more ‘backward’ economies have stronger incentives to limit product market competition in order to move closer to the world technology frontier.

This paper is by means in favor of trade protection. The recent proliferation wave of trade protection laws amongst developing countries implies that retaliation is now much more likely than ever before. One of the important results arising from our analysis is that in the face of retaliation domestic R&D is lower compared to a situation where neither country takes protection. Our model predicts that the prospect of retaliation reduces the incentive for traditional users of trade protection laws to use protection in the first place. We present some casual evidence in line with this prediction.

In section 2 we set up the model. Section 3 deals with the analysis of unilateral protection while section 4 discusses bilateral protection. Results are discussed in section 5 and section 6 concludes.

## **2. Theoretical Model**

### **2.1. The Benchmark (Free Trade) Model**

#### *2.1.1. Setup*

We consider a world consisting of two countries, which we call A and B. Each country hosts one firm, firm  $a$  and firm  $b$ , respectively. The firms engage in a two-stage game, first choosing a level of investment in cost-reducing R&D,  $g$ , and then compete in quantity in both national markets. More specifically, at stage 1: firm  $a$  and  $b$  simultaneously and independently decide on the level of cost-reducing R&D investment at a quadratic cost  $\gamma(g^2)/2$ . As in d’Aspremont and Jacquemin (1988),

we assume that the R&D environment is deterministic and that in the following stage each of the firms has constant marginal production cost given by  $c_a = \bar{c}_a - g_a - \phi_a g_b$  for firm  $a$  (and accordingly  $c_b = \bar{c}_b - g_b - \phi_b g_a$  for firm  $b$ ,  $a \neq b$ ), where  $g_a$  is the level of investment in R&D firm  $a$  makes in the first stage and similar for  $g_b$  which are the variables that interests us most.  $\phi_a$  is the absorption ability of firm  $a$  from firm  $b$ , and similar for  $\phi_b$ . Similar to Miyagiwa and Gao (2005) and without loss of generality, we assume  $\bar{c}_a = \bar{c}_b = \bar{c}$ , that means initially the firms have the same marginal production cost<sup>2</sup>, but once cost-reduction R&D is taken, their marginal production cost can be different. Our main assumption is that firms have a different ability to absorb the spillover from each other. In stage 2, we assume that the firms produce homogeneous and compete in quantity<sup>3</sup>. By assuming there are trade barriers between the domestic and foreign market and no profitable arbitrage opportunity exists, each firm regards each market as segmented.

We let (\*) denote the variables pertaining to a firm's export market. Thus,  $x_a^*$  and  $p_a^*$  respectively denote firm  $a$ 's export demand and price prevailing in foreign market, while  $x_a$  and  $p_a$  respectively denote the corresponding variables for the domestic market. We assume demands are linear and symmetric in the two national markets. Thus, firm  $a$ 's domestic demand and export demand is respectively given by

$$p_a(x_a, x_b^*) = \alpha - x_a - x_b^* \quad (1)$$

$$p_a^*(x_b, x_a^*) = p_b(x_b, x_a^*) = \alpha - x_a^* - x_b \quad (2)$$

where  $\alpha$  is the parameter pertaining to demand function and is normalized into 1 without loss of generality.

## 2.2 The second-stage (product market) game

In the second stage the marginal production costs,  $c_a = \bar{c}_a - g_a - \phi_a g_b$ , are pre-determined by R&D investment in the first stage. Markets are separated by an initial

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<sup>2</sup> Our calculation shows the initial level of marginal cost is irrelevant, firm-specific initial marginal cost causes more computational difficulty while leads to qualitatively the same results.

<sup>3</sup> Alternatively we follow Anderson *et al.*, (1995) and assume that the firms produce differentiated products and compete in prices, the result is qualitatively the same as the Cournot competition with differential product and the Cournot competition with homogeneous product in this presentation. So it indicates our results are robust against different modellings.

barrier to trade of size  $\bar{t}_A$  for firm  $b$  (and  $\bar{t}_B$  for firm  $a$ ) per unit shipped between them. The trade barrier can be a transport cost or any non-tariff barrier<sup>4</sup>.

Given this assumption on barriers to trade, firm  $a$ 's second-stage profits is written as

$$\pi_a(x_a, x_a^*; c_a) \equiv [p_a - c_a]x_a + [p_b - c_a - \bar{t}_B]x_a^* \quad (3)$$

Each firm maximizes this profit by choosing quantities for each national market independently, taking as given its competitor's quantities in the two markets. The first order conditions for firm  $a$  are as follow

$$1 - c_a - 2x_a - x_b^* = 0 \quad (4)$$

for the domestic market and

$$1 - c_a - 2x_a^* - x_b - \bar{t}_B = 0 \quad (5)$$

for the export market.

Eqs. (4) and (5) define firm  $a$ 's best-response function in the domestic and the foreign market, written  $x_a = r_a(x_b^*, c_a)$ , and  $x_a^* = r_a^*(x_b, c_a, \bar{t}_B)$ , respectively.

Due to the existence of barriers to trade and linear marginal costs the two national markets are effectively segmented and the equilibrium can be obtained by considering each national market separately. That is, we can get the Nash equilibrium  $\{\widehat{x}_a, \widehat{x}_b^*\}$  for the market in country  $a$  by first interchanging subscripts  $a$  and  $b$  in (5) to get firm  $b$ 's best-response function in its export market (market in country  $a$ ), and then solving it and (4) simultaneously:

$$\widehat{x}_a = \frac{1 - 2c_a + c_b + \bar{t}_A}{3} \quad (6)$$

$$\widehat{x}_a^* = \frac{1 - 2c_a + c_b - \bar{t}_B}{3} \quad (7)$$

where we denote with  $(\wedge)$  the values pertaining to the benchmark equilibrium. Eqs. (6) and (7) show that, in both the domestic market and the export market, the market share of firm  $a$  decreases with its own marginal cost and increases with the marginal cost of its competitor. That implies that firm  $a$  has an incentive to conduct cost-reducing R&D investment to expand its market share.

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<sup>4</sup> Non-tariff barriers (NTB) are trade issues such as technical, bureaucratic or legal questions, which can result in impediments to trade.

In this model there is reciprocal dumping, implying that each firm dumps into each other's market. The dumping margin is defined as the difference between the ex-factory export price  $p_a^* - \bar{t}_b$  and the home price  $p_a$  of the product. The ex-factory price is the theoretical price of the product of country  $a$  as it leaves the factory or put differently it is the price charged by  $a$  in the export market after deducting all the costs related to entering its export market  $b$  ( $p_a^* - \bar{t}_b$ ). Thus, the dumping margin is defined as.

$$\Delta_a = p_a - (p_a^* - \bar{t}_b) \quad (8)$$

It is easy to show that the dumping margin is positive for firm  $a$ , or  $\widehat{\Delta}_a = \frac{\bar{t}_A + 2\bar{t}_B}{3} > 0$ .

Similar result holds for firm  $b$  as well, confirming indeed that reciprocal dumping occurs.

Substituting the equilibrium quantities into the profits function, we have firm  $a$ 's equilibrium profit

$$\widehat{\pi}_a(c_a, c_b) \equiv \frac{1}{9} [2(1 + c_b - 2c_a)^2 - 4(1 + c_b - 2c_a)\bar{t}_B + 4(\bar{t}_B)^2 + 2(1 + c_b - 2c_a)\bar{t}_A + (\bar{t}_A)^2] \dots\dots\dots(9)$$

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

Substituting  $c_a = \bar{c}_a - g_a - \phi_a g_b$  into the equilibrium profit (9) and equilibrium output level (6), (7) yields the following expressions of them as functions of R&D investment level.

$$\widehat{\pi}_a(g_a, g_b) = \frac{1}{9} [(2D^2 + 4\bar{t}_B(D + \bar{t}_B) - 2D\bar{t}_A + \bar{t}_A^2 + 2g_a(2(D + \bar{t}_B) - \bar{t}_A)(\phi_b - 2) + 2g_a^2(\phi_b - 2)^2 + 2g_b(2(D + \bar{t}_B) - \bar{t}_A + 2g_a(\phi_b - 2))(1 - 2\phi_a) + 2g_b^2(1 - 2\phi_a)^2) \dots\dots\dots(12)$$

where  $D = c - 1$ . And the corresponding equilibrium output levels are

$$\widehat{x}_a(g_a, g_b) = \frac{1 - c + \bar{t}_A + (2 - \phi_b)g_a - (1 - 2\phi_a)g_b}{3} \quad (13)$$

$$\widehat{x}_a^*(g_a, g_b) = \frac{1 - c - 2\bar{t}_B + (2 - \phi_b)g_a - (1 - 2\phi_a)g_b}{3} \quad (14)$$

In this stage, the firms simultaneously and independently choose R&D investment levels,  $g_a$  and  $g_b$ , to maximize overall profit

$$\begin{aligned}
\Pi_a &= \widehat{\pi}_a(g_a, g_b) - \frac{\gamma_a}{2}(g_a)^2 \\
&= \frac{1}{9}[(2D^2 + 4\bar{t}_B(D + \bar{t}_B) - 2D\bar{t}_A + \bar{t}_A^2 + 2g_a(2(D + \bar{t}_B) - \bar{t}_A)(\phi_b - 2) \\
&\quad + 2g_a^2(\phi_b - 2)^2 + 2g_b(2(D + \bar{t}_B) - \bar{t}_A + 2g_a(\phi_b - 2))(1 - 2\phi_a) \\
&\quad + 2g_b^2(1 - 2\phi_a)^2] - \frac{\gamma_a}{2}(g_a)^2
\end{aligned}
\tag{15}$$

where the second term on the RHS is the quadratic R&D cost function taken from d'Aspremont and Jacquemin (1988), in which the quadratic form is used to model the nature of decreasing return to scale on innovation (the increasing difficulty to obtain innovation). That is, to obtain an innovation (a reduction on marginal production cost) level of  $g_a$ , a firm has to invest  $\frac{\gamma_a}{2}(g_a)^2$ . Different from Gao and Miyagiwa (2005), we adopt firm-specific innovation efficiency parameters, *i.e.*,  $\gamma_a$  for firm  $a$  and  $\gamma_b$  for firm  $b$ .

Differentiating the overall profit function  $\Pi_a$  with respect to R&D investment level  $g_a$ , we have

$$\frac{\partial \Pi_a}{\partial g_a} = \frac{1}{9}[g_a(4(\phi_b - 2)^2 - 9\gamma_a) + 2(2(D + \bar{t}_B) - \bar{t}_A + g_b(2 - 4\phi_b))(\phi_b - 2)]
\tag{16}$$

Let (16) be equal to 0, and from this first-order condition we have that at the optimum<sup>5</sup>:

$$g_a = \frac{2(\bar{t}_A - 2(D + \bar{t}_B) + g_b(4\phi_a - 2))(\phi_b - 2)}{4(\phi_b - 2)^2 - 9\gamma_a}
\tag{17}$$

To see how firm  $a$  reacts to firm  $b$ 's R&D investment choice, differentiating  $g_a$  with respect to  $g_b$  yields

$$\frac{\partial g_a}{\partial g_b} = \frac{2(4\phi_a - 2)(\phi_b - 2)}{4(\phi_b - 2)^2 - 9\gamma_a}
\tag{18}$$

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<sup>5</sup> The second order condition requires that  $\gamma_a > \frac{4(\phi_b - 2)^2}{9}$ . In the analysis of next section, we assume  $\gamma_a = \gamma_b = 2$  which is enough to guarantee the S.O.C and ease calculating load.

Thus  $\frac{\partial g_a}{\partial g_b} > 0$  if and only if  $\phi_a > \frac{1}{2}$ <sup>6</sup>. That implies firm  $a$ 's optimal R&D investment level increases with that of firm  $b$  if firm  $a$  is sufficiently efficient in absorbing spillover from firm  $b$  ( $\phi_a > \frac{1}{2}$ ), otherwise it decreases.

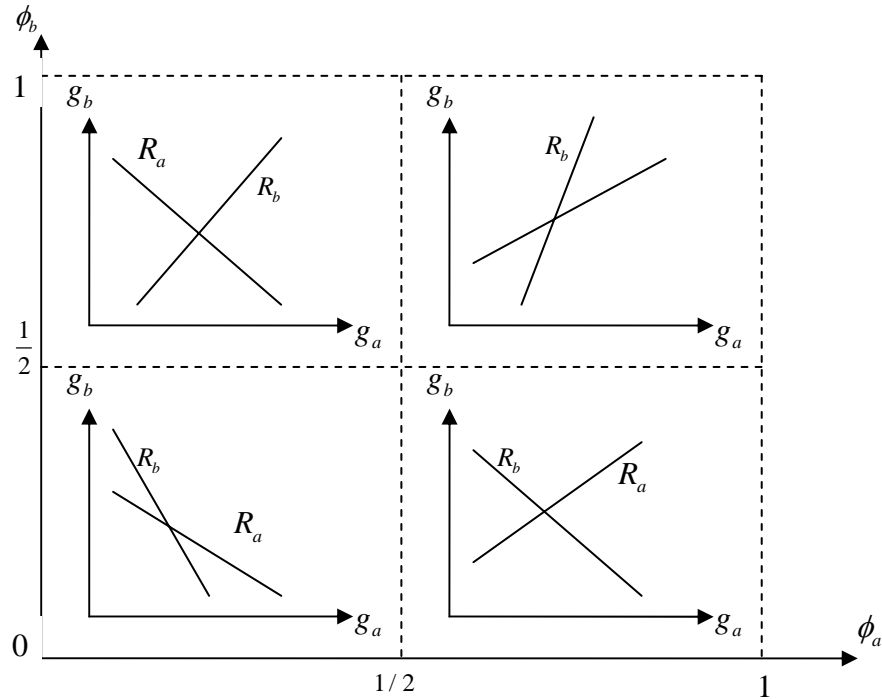
**Proposition 1:** *Firm  $b$ 's R&D investment is a strategic complement for firm  $a$ 's R&D investment provided firm  $a$  is sufficiently efficient in absorbing spillover from firm  $b$  ( $\phi_a > \frac{1}{2}$ ), otherwise it is a strategic substitute for firm  $a$ 's R&D investment if  $\phi_a < \frac{1}{2}$ .*

Intuitively this implies that how firm  $a$  reacts to a change on its foreign competitor  $b$ 's R&D investment depends on how efficient firm  $a$  is in absorbing spillover of innovation from its competitor. Or put differently when firm  $a$  finds it easy to copy, an increase in firm  $b$ 's R&D levels will induce it to do the same. This is what is referred to as strategic complementarity of R&D. However, when firm  $a$  has a weak capacity to absorb, an increase in firm  $b$ 's R&D level will meet a decrease in the R&D level of  $a$ . This is referred to a strategic substitutability.

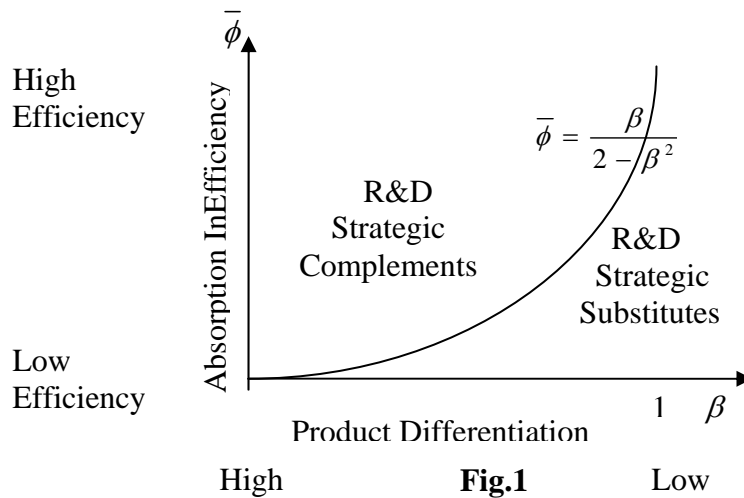
When firms have the same efficiency in absorbing,  $\phi_a = \phi_b$ , and when both are not weak in absorbing, firm-level R&D investments are strategic substitutes as shown by Gao & Miyagiwa (2005). But when firms have the same efficiency in absorbing,  $\phi_a = \phi_b$ , and when both are good in absorbing, firm-level R&D investments are strategic complementarity. While firms are heterogeneous in absorbing efficiency, the R&D investment of competitor is strategic substitute for the weak firm, and strategic complementarity for the strong firm. We summarize the results in the following figure.

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<sup>6</sup> This threshold value is not related to the innovation efficiency parameter of its competitor. This property is robust with *ad valorem* and *Iceberg* trade cost function.



For Betrant Model with product differentiation, we have the results depicted in the following figure.



**Fig.1**

**Corollary 1:** Given a firm's absorption efficiency level  $\phi$ , when product differentiation increases (decreasing  $\beta$ ), a firm's R&D investment is more likely to be a strategic complement for another firm's R&D investment.

#### 2.4. R&D and Trade Policy

The benchmark model discussed above implies reciprocal dumping arises due to the existing trade impediments between countries. For the purpose of our analysis on

the impact of (unilateral and bilateral) trade policy, we now distinguish between  $\bar{t}_A$  the *initial* level of trade impediments (status quo benchmark) and  $t_A$  the *change* in trade barriers resulting from trade policy by country  $A$  which can be positive or negative. Hence the total amount of trade barriers in the model under new trade policy are  $\bar{t}_A + t_A$ . A positive value of  $t_A$  represents additional trade protection for instance in the form of antidumping protection (AD)<sup>7</sup> imposed by country  $A$ . Clearly,  $t_A + \bar{t}_A$  is a simple linear combination of  $t_A$  and  $\bar{t}_A$ , thus all the previous results naturally extend to the cases of new trade policy, simply by substituting  $t_A + \bar{t}_A$  the new tariff into the corresponding equations. While our benchmark model is just a special case in which  $t_A = t_B = 0$ . Without loss of generality, for the moment we further assume  $\bar{t}_A = \bar{t}_B$  and  $t_A = t_B = 0$ , that is we start from the status quo situation in which both countries have the same level of trade barriers. Substituting them into the corresponding equilibrium equations, we get the relevant equilibrium values for the status quo (the benchmark).

Now we derive the Nash equilibrium level of R&D investment  $\{\widehat{g}_a, \widehat{g}_b\}$  by first interchanging subscripts  $a$  and  $b$  in (17) to get firm  $b$ 's best-response function in its R&D decision, and then solving it and (17) simultaneously:

$$\widehat{g}_a = \frac{((t_A + \bar{t}_A)(3 + 2(\phi_a - 2)\phi_a) + 2(D(1 + 2(\phi_a - 3)\phi_a) - (t_B + \bar{t}_B)(1 + \phi_a)))(\phi_b - 2)}{5 + 2\phi_b(3\phi_b - 8) + \phi_a^2(6 + 4(\phi_b - 2)\phi_b) - 4\phi_a(4 + \phi_b(2\phi_b - 3))} \dots\dots\dots(20)$$

We have the equilibrium level for firm  $b$  simply by interchanging the subscripts  $a$  and  $b$  in (20). By substituting the equilibrium R&D investment levels into the previous functions, we immediately obtain the equilibrium outputs and profits. But in the remainder of the paper we focus on R&D incentives and we evaluate the impact of (unilateral and bilateral) trade protection on them.

To investigate how firm  $a$ 's R&D investment decision is affected by the tariff levels, we derive the first order differentiation of  $g_a$  with respect to the tariff  $t_B$

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<sup>7</sup> In principle our results hold for a continuum of values of  $t_A$ . The antidumping duty which would set  $t_A$  equal to the dumping margin  $\Delta_b$  as in Blonigen and Haynes (2002) is just a special case in our model

imposed by country  $b$  on firm  $a$ 's exports to country  $b$  market, and the tariff  $t_A$  imposed by country  $a$  on imports from firm  $b$  located in foreign country B.

$$\frac{\partial \widehat{g}_a}{\partial t_B} = \frac{2(1 + \phi_a)(2 - \phi_b)}{5 + 2\phi_b(3\phi_b - 8) + \phi_a^2(6 + 4(\phi_b - 2)\phi_b) - 4\phi_a(4 + \phi_b(2\phi_b - 3))} \dots\dots\dots(21)$$

$$\frac{\partial \widehat{g}_a}{\partial t_A} = \frac{(3 + 2(\phi_a - 2)\phi_a)(\phi_b - 2)}{5 + 2\phi_b(3\phi_b - 8) + \phi_a^2(6 + 4(\phi_b - 2)\phi_b) - 4\phi_a(4 + \phi_b(2\phi_b - 3))} \dots \quad (22)$$

Immediately, we have the following result shown that the effect of a foreign tariff on the R&D investment of firm  $a$  is positive if and only if

$$\phi_b < \widetilde{\phi}_b = \frac{8 - 6\phi_a + 4\phi_a^2 - \sqrt{34 + 4\phi_a(10 - \phi_a(21 + 2(\phi_a - 8)\phi_a))}}{6 + 4(\phi_a - 2)\phi_a} \dots\dots\dots(23)$$

Which indicates that only if the foreign firm  $b$ 's absorption ability is below a threshold value  $\widetilde{\phi}_b$ , firm  $a$  increases its R&D investment when foreign tariff  $t_B$  goes up. Similarly, we have that only if firm  $b$ 's absorption ability is above this threshold value, firm  $a$  increases its R&D investment when the tariff  $t_A$  on foreign import imposed by its home country goes up.

**Lemma 1:** *Firm A's R&D investment increases with foreign tariff  $t_B$  if and only if  $\phi_b < \widetilde{\phi}_b$ , and increases with tariff  $t_A$  against foreign imports if and only if  $\phi_b > \widetilde{\phi}_b$ .*

Intuitively this implies that when a domestic firm faces a tariff in its export market it will increase its R&D provided its foreign competitor is not a good copier. And the opposite holds when the foreign firm is a good copier, in that case a tariff abroad will reduce its R&D levels. This is what we call the *foreign effect*. The second part of the Lemma deals with the situation where a domestic firm is protected by a domestic tariff against imports from abroad. In this case the domestic firm has an incentive to increase its R&D spending but only in the case where its foreign competitor is a good copier. And the opposite holds when the foreign firm is a bad copier. This is what we call the *own effect*. When country A imposes a tariff on imports from B, the tariff  $t_A$  is not directly targeted at the firm in A, but it has an indirect effect on firm A's R&D choice via its competitor B's R&D choice.

Now we evaluate the relative magnitude of effect of a tariff of home country effect on R&D level and that of a foreign tariff. We have  $\left| \frac{\partial g_a}{\partial t_A} \right| > \left| \frac{\partial g_a}{\partial t_B} \right|$  if and only if

$\phi_a < \frac{1}{2}(3 - \sqrt{7}) \approx 0.177$ . So we have the following lemma.

**Lemma 2:** *The impact on a firm's equilibrium R&D investment level of a tariff imposed by its home country on the imports from a foreign firm is more significant than the foreign tariff if and only its spillover absorption rate is below a threshold*

$$\widehat{\phi}_a = \frac{1}{2}(3 - \sqrt{7}).$$

### 3. Unilateral Trade Protection

First, we analyze the effect of unilateral trade protection, that is, when only one country adopts trade protection. Without loss of generality, we assume it is country A that increases its tariff  $t_A$  against imports from country B.

Under unilateral protection by country A we assume this tariff is not prohibitively high for the firms from country B to keep exporting in the presence of trade protection.

For the remainder of the analysis, in particular Lemma 1 and Lemma 2 are important. From **Lemma 1** we know that when country A imposes a tariff against imports, the R&D effect on its own firm in A depends on the efficiency in copying of firm in country B, the protection will lower its R&D spending if the foreign firm is a bad copier, but if the firm in B is a good copier, the tariff will increase its R&D. In terms of the R&D of the trade partner, **Lemma 1** tells us that R&D response by the foreign firm in B to trade protection by country A also depends on the efficiency in copying of the firm in A. If the firm in A is an efficient copier it will reduce its R&D spending when facing protection in its export market. However, when the firm in A is a lowly efficient copier, trade protection by country A will increase its R&D spending. It also tells us that when country B imposes a tariff against imports, the R&D effect on firm in A depends on the efficiency in copying of firm in country B, the protection will lower its R&D spending if the foreign firm is a good copier, but if the firm in B is a bad copier, the tariff will increase its R&D.

Finally, Lemma 2 points out that the effect in terms of R&D investment change of tariff protection by country A in equilibrium will be stronger than the the foreign

tariff by country B for the firm in A if firm A's spillover absorption ability is below a threshold value. This is important for the graphical analysis we pursue below since it limits the relative magnitude of the shifts of firms' best response functions due to trade protection by A.

Thus, conditioned on the copy efficiency of firms, we have several possible configurations as demonstrated below. To make clear-cut prediction, we focus on some special scenario, we assume  $\phi = 0$  for a firm in a developed country, and  $\phi = 1$  for a firm in a developing country, to capture the idea that intellectual property rights are well respected in developed countries while seriously violated in developing countries.

### 3.1.) Unilateral Protection: "Developed versus Developed"

Firstly us consider the case where firms from both countries are bad copier. This can be thought of as two developed countries competing with each other. From Proposition 1 we know that in such a case for each firm the R&D investment of its competitor is a strategic substitute for its own R&D investment and best response functions are decreasing. Thus firm  $a$  and firm  $b$  have their reaction functions depicted as in Fig.2.a, in which  $E$  is the original equilibrium under free trade (the benchmark case). With unilateral trade protection imposed by country A, the firm in B's reaction curve moves outward (right-ward), and firm  $a$ 's reaction curve moves inward (left-ward). Thus we have a new equilibrium, in which the firm in A decreases its investment on R&D while the firm in B increases its R&D investment.

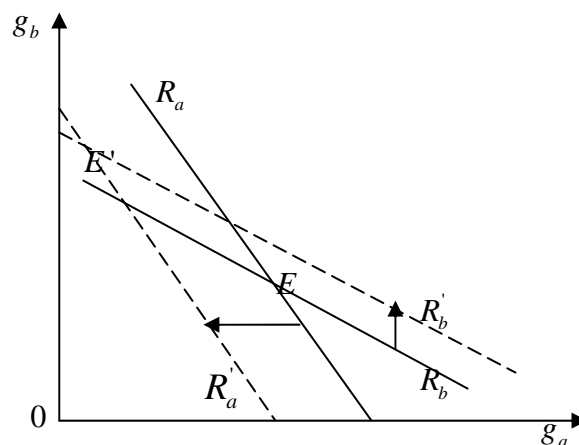


Fig.2.a.  $\phi_a = 0, \phi_b = 0$

$$g_a^{E'} < g_a^E \text{ and } g_b^{E'} > g_b^E$$

### 3.2.) Unilateral Protection: “Developed versus Developing”

Next we turn to the case where country A is a developed country with the firm in A is a bad copier and the firm in a developing country B is good copier. From Proposition 1 we know that for the bad copier in A, the R&D investment of the firm in B is a strategic substitute, resulting in a downward sloping best response function. While for the firm in B, the R&D investment of its competitor in A is a strategic complementarity, resulting in an upward sloping best response function. Thus firm *a* and firm *b* have their reaction functions depicted as in Fig.2.b, in which *E* is the original equilibrium under the benchmark case. From Lemma 1 we know that with unilateral trade protection by country A, the firm *b*'s reaction curve moves outward (up-ward), and firm *a*'s reaction curve moves outward (right-ward). Thus we have a new equilibrium *E'*, in which firm *a* increases its R&D investment but firm *b* decreases its R&D investment.

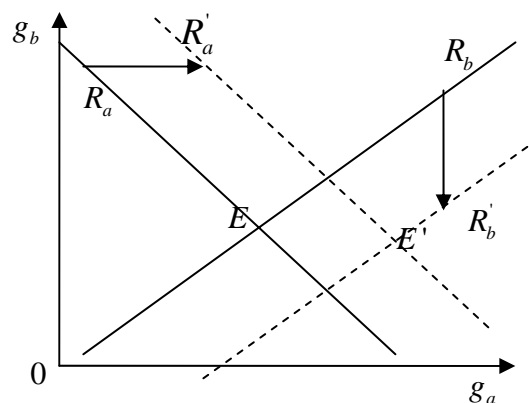


Fig.2b.  $\phi_a = 0$ ,  $\phi_b = 1$

$$g_a^E < g_a^{E'} \text{ and } g_b^E < g_b^{E'}$$

### 3.3) Unilateral Protection: “Developing” versus “Developed”

For completeness we also want to consider what happens in the case where country A is a developing country with high efficiency in copying would use unilateral trade protection against a developed country B with low efficiency in copying. The analysis would be exactly the opposite as the one described in the section above (3.2.). Unilateral protection by the developed country A would increase R&D of its domestic firms and decrease R&D spending of firms in B.

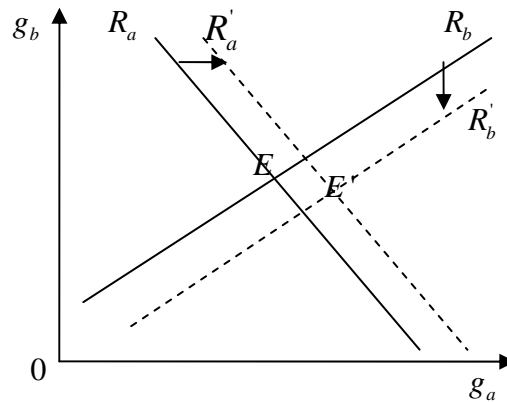


Fig.3.c.  $\phi_a = 1, \phi_b = 0$

$$g_a^E < g_a^{E'} \text{ and } g_b^{E'} < g_b^E$$

### 3.4.) Unilateral Protection: “Developing versus Developing”

We finally consider the case where both firms in both countries A and B are efficient in copying that is their cost to innovate lies below a threshold value  $\phi_a = 1$  and  $\phi_b = 1$ . Proposition 1 stated that in such a case for each firm the R&D investment of its competitor is a strategic complement for its own R&D investment. Thus firm *a* and firm *b* have upward sloping reaction functions depicted as in Fig.2.d, in which the reaction curve of firm *a* is  $R_a$  and the reaction curve of firm *b* is  $R_b$ , and  $E$  is the original benchmark equilibrium. With unilateral trade protection imposed by country A, firm *b*'s reaction curve moves downward to  $R'_b$ , and firm *a*'s reaction curve moves outward (right-ward) to be  $R'_a$ . Thus with unilateral protection by country A we have a new equilibrium  $E'$ , in which the firm in A increases its investment in R&D and the firm in B reduces its R&D investment.

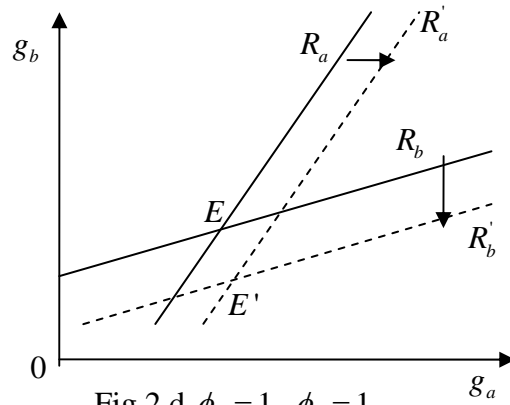


Fig.2.d.  $\phi_a = 1, \phi_b = 1$

$$g_a^E < g_a^{E'} \text{ and } g_b^{E'} < g_b^E$$

Or, put differently, in an industry where two countries have a strong capacity to copy, unilateral trade protection stimulates the innovation efforts of the domestic firms but slows down R&D investment by the foreign firms.

#### 4. Bilateral Trade Protection

After considering unilateral protection by country A, we now turn to the scenario of bilateral protection in which country B follows suit and also adopts an import tariff of the same level that is  $t_A = t_B$ . Again we assume this tariff is not prohibitively high and allows all firms to continue exporting even in the presence of bilateral trade protection. Obviously this is a simplifying assumption but it allows us to easily distinguish the effects of unilateral versus bilateral protection.<sup>8</sup>

From **Lemma 1** and **Lemma 2** we know that a tariff by country B increases the R&D level of firm *b* if and only if the firm in A is efficient copier. The effect on firm *a* of a tariff by B also depends on the copying efficiency of the firm in B. If the firm in B is a bad copier a tariff by B will raise R&D investments of firm in A otherwise it will lower them. Moreover, we know that the own effect dominates the foreign effect. That is, for the firm in A, the effect of a tariff by A on its R&D dominates the effect of a foreign tariff imposed by country B. and similarly for the firm in B. Thus, conditioned on the innovation efficiency of firms, again we have several configurations as demonstrated below.

<sup>8</sup> In this paper we do not go in search of the first-best type of trade policy. The symmetry we assume largely simplifies things and allows us to focus on R&D incentives.

#### 4.1.) Bilateral Protection: “Developed versus Developed”

We consider what happens if both countries are developed countries with firms lowly efficient in copying. Thus both firms have downward sloping best response functions depicted as in Fig.3a, Starting from the unilateral protection scenario in which only country A adopts trade protection, then if country B also adopts protection, *i.e.*, increases  $t_B$ , the reaction curve of the firm in B shifts back (down-ward), and overtakes the original reaction curve  $R_b$ , the new one is  $R_b''$ ; and the reaction curve of the firm in A shifts back (right-ward) as well, that is the new reaction curve  $R_a''$ . Thus we have the corresponding equilibrium under bilateral trade protection,  $E''$ , in which  $g_a^{E'} < g_a^{E''} < g_a^E$  and  $g_b^{E''} < g_b^E < g_b^{E'}$ . So with the adoption of trade protection by country B, the firm in A increases R&D investment while the firm in B reduces R&D investment. However, the R&D investment level under bilateral protection is lower for both firms compared to that under free trade. Thus the net effect of bilateral trade protection is negative for both firms.

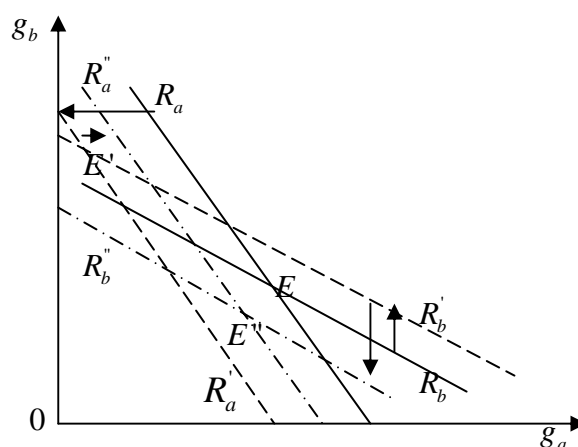


Fig.3.a.  $\phi_a = 0, \phi_b = 0$

$$g_a^{E'} < g_a^{E''} < g_a^E \text{ and } g_b^{E''} < g_b^E < g_b^{E'}$$

#### 4.2.) Bilateral Protection: “Developed versus Developing”

Now let us suppose that country A is a developed country with a firm in A that is a bad copier while the firm in B is a good copier. Thus firm in A and the firm in B have their reaction functions depicted as in Fig.3.b. We start from the unilateral protection scenario in which only country A adopted trade protection. When a developing country B that hosts a good copy firm retaliates and adopts protection, *i.e.*, increases  $t_b$ , the reaction curve of the firm in B shifts back up-ward), the new

one is  $R_b'$ ; and the reaction curve of the firm in A shifts back (left-ward) as well, the new reaction curve is  $R_a''$ . Thus we have the corresponding equilibrium under bilateral trade protection,  $E''$ , in which  $g_a^E < g_a^{E''} < g_a^{E'}$  and  $g_b^{E'} < g_b^{E''} < g_b^E$ . So with the adoption of trade protection by the developing country B, both firms reduce R&D investment. However, compared to that under the benchmark equilibrium, the bad copy firm in A's R&D investment level is greater while the good copy firm in B's R&D investment is lower. Thus the net effect of bilateral trade protection is positive for the firm in A, but negative for the firm in B.

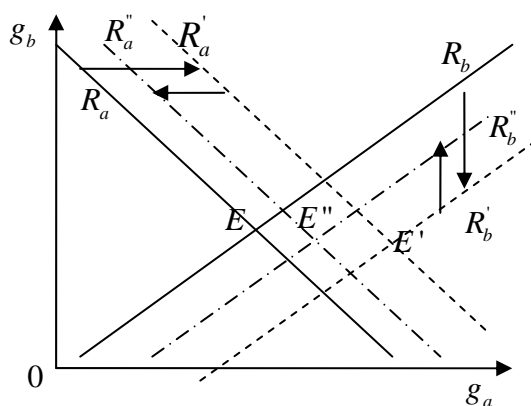


Fig.3b.  $\phi_a = 0, \phi_b = 1$

$$g_a^E < g_a^{E''} < g_a^{E'} \text{ and } g_b^{E'} < g_b^{E''} < g_b^E$$

### 3.3) Bilateral Protection: “Developing” versus “Developed”

For completeness we also want to consider what happens in the case where country A is a developing country with high efficiency in copying and B is a developed country with low efficiency in copying. Starting from the unilateral protection scenario in which only country A adopts trade protection, then if country B also adopts protection, *i.e.*, increases  $t_b$ , the reaction curve of the firm in B shifts back (up-ward), and overtakes the original reaction curve  $R_b$ , the new one is  $R_b''$ ; and the reaction curve of the firm in A shifts back (right-ward) as well, the new reaction curve is  $R_a''$ . Thus we have the corresponding equilibrium under bilateral trade protection,  $E''$ , in which  $g_a^{E''} < g_a^E < g_a^{E'}$  and  $g_b^{E'} < g_b^E < g_b^{E''}$ . So with the adoption of trade protection by the developed country B, both firms increase R&D investment. However, compared to that under the benchmark equilibrium, the good copy firm in A's R&D investment level is lower while the bad copy firm in B's R&D investment is

greater. Thus the net effect of bilateral trade protection is negative for the firm in A, but positive for the firm in B.

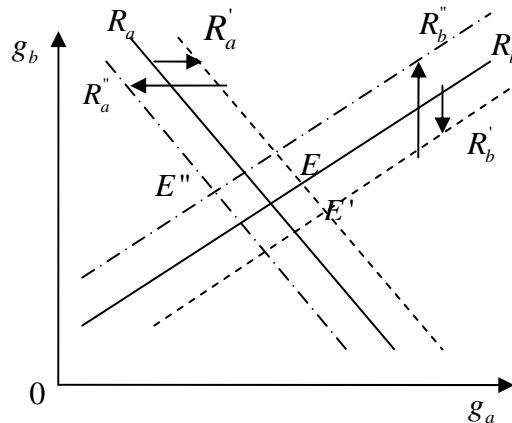


Fig.3.c.  $\phi_a = 1, \phi_b = 0$

$$g_a^{E''} < g_a^E < g_a^{E'} \text{ and } g_b^{E'} < g_b^E < g_b^{E''}$$

#### 4.4.) Bilateral Protection: “Developing versus Developing”

If both countries are developing countries and efficient in copying, firms’ best response functions are upward sloping as depicted in Fig.3.d. Starting from the unilateral protection scenario (see 3.1. above) in which only country A adopts trade protection, if country B also adopts protection, *i.e.*, increases  $t_B$ , the reaction curve of the firm in B shifts back (up-ward), but to a lower degree (by **Lemma 2**), and the new reaction curve is  $R''_b$ ; and the reaction curve of the firm in A shifts back as well (left-ward), but to a greater degree (by **Lemma 2**). Thus we have the corresponding equilibrium under bilateral trade protection,  $E''$ , in which  $g_a^{E''} < g_a^E < g_a^{E'}$  and  $g_b^{E'} < g_b^{E''} < g_b^E$ .

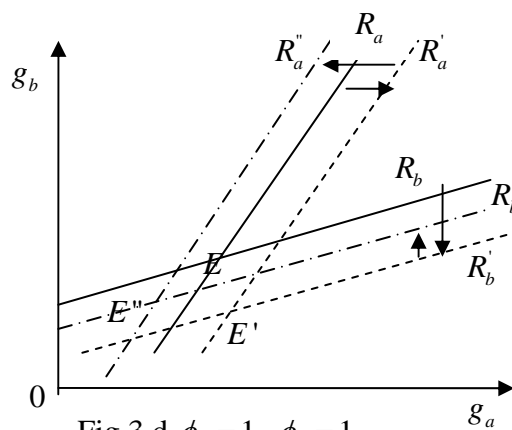


Fig.3.d.  $\phi_a = 1, \phi_b = 1$

$$g_a^{E''} < g_a^E < g_a^{E'} \text{ and } g_b^{E'} < g_b^{E''} < g_b^E$$

So with the adoption of trade protection by a developed country B, the firm in A reduces R&D investment while the firm in B increases R&D investment. However, the total R&D investment level is lower for firm in A and greater for firm in B compared to that under the benchmark case in the absence of any AD. Thus the net effect of bilateral trade protection on R&D is positive firm in B and negative for firm in A.

We summarize all the previous results in the following table. Using arrows in Table 1 we indicate the direction of R&D investment in the firm in A and the firm in B under different trade policy scenarios: unilateral trade protection and bilateral trade protection. The last row indicates the “net effect” that is the total amount of R&D per firm compared to the benchmark equilibrium.

**Table 1: Effects of Trade Protection on Firm’s R&D**

	Developed vs. Developed		Developed vs. Developing		Developing vs. Developed		Developing vs. Developing	
Innovation efficiency	$\phi_a = 0, \phi_b = 0$		$\phi_a = 0, \phi_b = 1$		$\phi_a = 1, \phi_b = 0$		$\phi_a = 1, \phi_b = 1$	
R&D Investment	$g_a$	$g_b$	$g_a$	$g_b$	$g_a$	$g_b$	$g_a$	$g_b$
Country:	<b>(1)</b>	<b>(2)</b>	<b>(3)</b>	<b>(4)</b>	<b>(5)</b>	<b>(6)</b>	<b>(7)</b>	<b>(8)</b>
A protects <b>(a)</b>	↓	↑	↑	↓	↑	↓	↑	↓
B retaliates <b>(bb)</b>	↑	↓	↓	↑	↓	↑	↓	↑
Net Effect of (a) and (b)	⊖	⊖	⊕	⊖	⊖	⊕	⊖	⊖

Note: When country A liberalizes this is a reduction of  $t_A$  compared to the benchmark equilibrium. When country A protects this is an increase in  $t_A$  compared to the benchmark equilibrium. When B retaliates this implies that we compare firms’ responses to the unilateral protection equilibrium. The “Net effect” row implies that we compare firms’ responses under bilateral protection to the benchmark equilibrium.

**Note:**

**1. Between developed countries, unilateral protection reduces R&D of domestic firm and increases that of foreign firm, no interest to initiate protection. Liberalization prevails.**

**2. Between developing countries, unilateral protection increases R&D of domestic firm and reduces that of foreign firm, bilateral protection offsets it, and the net effect is negative. A situation of Prisoner Dilemma.**

**3. When a developed country faces a developing country, unilateral protection increases R&D of firms in developed country, reduces that in developing country. Retaliation by the developing**

country partially offsets the unilateral effect. The net effect is positive for developed country while negative for developing country. The developed country has intention to initiate protection.

4. When a developing country faces a developed country, unilateral protection increases R&D of firms in developing country, reduces that in developed country. Retaliation by the developed country overtake the unilateral effect. The net effect is positive for developed country while negative for developing country. The developing country has no intention to initiate protection. But once the developing country initiates protection, the developed country will retaliate.

## 5. Discussion of Results and Implications

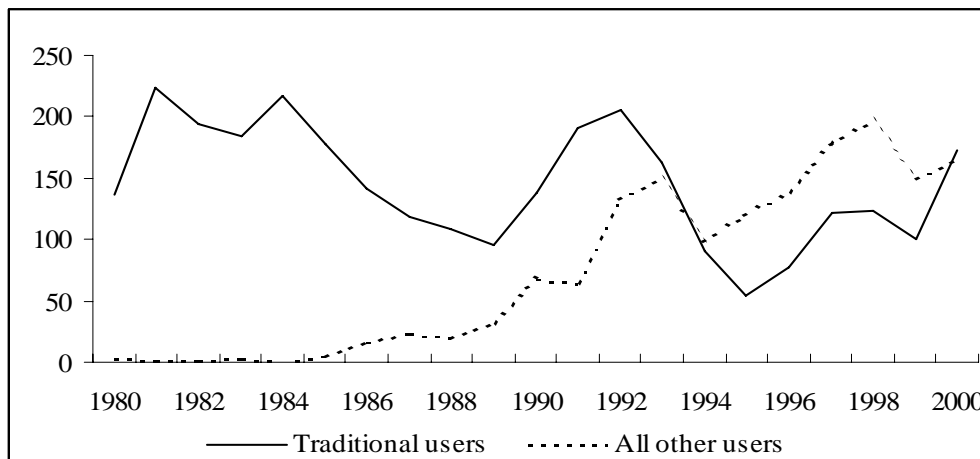
Our results show that the effects of trade protection on firm-level R&D differ across firms. While unilateral trade protection by country A can boost productivity of firms in A (cells 3a, 5a and 7a), it hurts the productivity of highly efficient firms in A (1a).

Interestingly, in those cases where unilateral trade protection boosts R&D efforts of domestic firms, once retaliation is allowed for and bilateral protection kicks in, these same domestic firms may lose or gain, depending on the firm's ability to absorb spillover from its competitor. This can be seen from the "net effect" at the bottom of column 3, 5 and 7 in Table 1. Hence, while a country may be inclined to protect its firms through antidumping protection, retaliatory action by a trade partner may imply that the net amount of R&D spending will be lower than under the benchmark equilibrium in the absence of any antidumping protection. Results in Table 1 would suggest that in the absence of any retaliation, countries may be inclined to use unilateral (AD) protection to boost R&D investment of domestic firms in industries where they lag behind in innovation ability. However, once retaliation becomes a distinct possibility, countries are more likely to refrain from using antidumping protection since the results in Table 1 show that R&D efforts under bilateral protection are below benchmark levels.

The recent proliferation of Antidumping laws especially amongst developing countries has substantially increased the retaliatory power of these developing countries (Prusa, 2001). Zanardi (2004) reports that while 37 countries had an AD law in 1980, this number increased to 93 countries by the end of 2000 including countries like Mexico, China, India, Taiwan, Turkey, Peru, Egypt etc. to name just a few. The proliferation does not seem to be confined to any particular region but includes developing countries from Asia, Latin-America and former Eastern Europe and seems to be primarily driven by retaliation motives. That is, especially those countries that in the past were subject to antidumping duties in their export markets seem more likely

to pass trade protection laws of their own (Vandenbussche and Zanardi, 2008). Before the diffusion of Antidumping laws took off, there were only a handful of countries using AD protection unilaterally. They involved the US, EU, Australia, Canada and New Zealand. The countries these traditional users targeted mainly involved less developed countries in Latin-America, Asia and former Eastern-Europe. At that time these traditional users of antidumping did not face much risk of retaliation and cases were plentiful. However, in recent years the number of AD initiations by the traditional users seems to have slowed down. This is illustrated in Figure 1. Around the same time as the AD initiations by the “new users” of AD started to shoot up as indicated by the dotted line, we observe a slowdown in the number of AD cases initiated by the traditional users as indicated by the full line.

**Figure 1: Antidumping Initiations by Traditional and New Antidumping users**



Notes: i) Traditional users include Australia, Canada, EU, New Zealand, and United States.  
 ii) all other users: a complete list of all new users can be found in Vandenbussche and Zanardi (2008)

This slowdown of AD cases by traditional users is in line with the predictions of our model. Based on our findings we would expect that when retaliation becomes a distinct possibility there will be less AD protection initiated by the traditional users in the first place.

## 6. Conclusion

This paper looks at the interaction of trade policy and firms' incentives to innovate. We use a two-country two-firm model with firms in each country both selling at home and exporting abroad. Our results suggest that countries whose domestic firms lag behind in terms of innovation efficiency have an incentive to unilaterally protect their industry to boost R&D investment. This incentive only arises when domestic firms are laggards in innovation. Unilateral protection would hurt the R&D investment of already efficient firms. We also shed some new light on the recent proliferation wave of trade protection laws amongst developing countries. Our model predicts that the prospect of retaliation for traditional users of antidumping protection like the US, EU, Australia and Canada reduces their incentive to use protection in the first place since bilateral protection results in a loss of R&D for their firms compared to a situation where neither country takes protection. Therefore based on our model we would expect a slowdown in the number of antidumping protection cases by traditional users. A casual look at the data seems to support this prediction.

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