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ENVIRONMENTAL PROTECTION UNDER BILATERAL TRADE AND IMPERFECT COMPETITION; FREE TRADE VERSUS STRATEGIC TARIFFS

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Environmental protection under bilateral trade and imperfect competition; free trade versus strategic tariffs*

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Abstract

This paper examines the interplay of environmental policies with trade policies (tariffs) in a context of bilateral trade and imperfect competition. Production generates a negative environmental externality. Governments strategically design their policies to correct for this externality taking into account that their firms compete with foreign firms both in the domestic end foreign markets. We show that bilateral reductions of tariffs (free trade agreements) may result in tougher or weaker environmental policies. The more responsive the social cost of production is to the environmental instrument, the more likely that a freer trade induces tougher environmental policies. On the other hand, these strategic policies can also be tougher or weaker than the globally optimal (international coordination) policies. It is the tradeoff between rent shifting and pollution exporting incentives what determines the sign of the distortion introduced by strategic interaction of governments. The model is flexible in terms of the specification of the environmental instruments. Three particular specifications are analyzed that correspond to frequent examples in the literature: the use of standards, the use of taxes on pollution when firms choose among different technologies, and the use of taxes on pollution related output.

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Key words: Environmental policy, bilateral trade, imperfect competition

1.-Introduction

The interplay of environmental and trade policies has aroused a considerable amount of interest in recent times, both in theoretical and policy discussions. In particular, it is by now popular to argue that trade concerns may cause governments' to weaken their environmental policies. As an example, recent moves towards free trade, like the NAFTA, have been seen as threats to environmental standards. As Kennedy (1994, p. 49) points out, it has been argued that "freer trade will lead governments to relax their environmental standards in order to gain a competitive edge over their trading partners". The main goal of this paper is to analyze this issue in a context of bilateral trade, imperfect competition, and negative externalities associated with production.

We study the effect on environmental policies that can be expected from a free trade agreement. Before the agreement is signed, governments can set both tariffs on imports and environmental policies. After the agreement, the use of tariffs is forbidden. We analyze a symmetric model of the strategic interplay of governments and firms. Governments independently and simultaneously choose environmental policies and, in absence of trade agreements, trade policies. Then firms located in each of the countries take their output decisions, both for the domestic market and for export to the other country. Firms seek to maximize profits given tariffs and environmental policy variables. Governments, on the other hand, are interested in social welfare, taken here as net consumer and producer surplus plus tariff revenue, if any, minus environmental damage. The model is flexible with respect to the definition of environmental instruments. Particular cases that we study are pollution standards, taxes on emissions inducing cleaner technologies, and taxes on polluting output.

To our knowledge, this is the first paper to formally consider the effects of bilateral reductions (elimination) of tariffs in a model of strategic interaction[1]. This enables us to explicitly analyze the effect of a free trade agreement on environmental policies. We show that this effect crucially depends on the responsiveness of the social marginal cost of production, including environmental damage, to the environmental policy instrument. Thus, contrary to the conjecture mentioned above, if the environmental instrument has a large impact, directly or through the induced reduction in output, in lowering the social cost of production then environmental policies are strengthened by the the liberalization of trade. As an illustration of the result, and for each of the three types of policy instruments considered, we give examples

[1] Ludema and Wooton (1994) compare a situation of free trade with other of managed trade. However they assume perfect competition. Also, in their model only one country pollutes, and only one (the other) cares about pollution. Then in the situation of managed trade the tariff set by the non polluting country has components designed to reduce pollution. Trade liberalization makes this instrument for pollution control disappear.

for which a free trade agreement results in tougher policies and others for which the result is a weaker policy.

The second goal of the paper is to evaluate, using our general specification, environmental policies under trade as compared to the socially efficient (global coordination) policies. This is a topic that has been studied by a number of authors. Both Kennedy (1994) and Hung (1994) analyze this issue in models that are particular cases of the one studied here. Also, both conclude that environmental policies under free trade would be weaker than efficient. We show that this is not generally true. The source of the distortion introduced by trade considerations in a symmetric situation is the higher responsiveness of output to decentralized, unilateral changes in environmental policies as compared to coordinated changes. This higher responsiveness can work both in favor or against tougher environmental policies. To understand the reason, notice that environmental policy instruments can have two effects on social welfare. The first is a direct effect on the social cost of production: tougher policies imply lower costs of emissions but higher cost of inputs, in general. The second is an indirect effect through changes in output: tougher policies reduce output, then social costs will be lower but consumer's surplus will fall too. The efficient, coordinated policy would balance these two effects. When the indirect effect is positive, i.e., when the marginal willingness to pay is lower at the efficient solution than marginal social cost, then policy competition induces the government's to strengthen environmental policies: the responsiveness of output to policy is now higher and so output is reduced more than under coordination, so that the increase in surplus (indirect effect), is larger than the increase in social cost (direct effect).

We apply this general analysis to particular examples of policy instruments. For the case in which the only policy instrument is a tax on polluting output, we show that both policies, i.e., coordinated and decentralized policies, always coincide. The reason is that a tax on output has no (direct) effect on the social cost of production. It only represents a transfer from firms to the governments. Therefore, efficiency implies setting a tax such that marginal willingness to pay coincides with marginal social cost of production. Thus, given what was said in the previous paragraph, the decentralized policies coincide with the efficient, coordinated ones[2]. For the case of standards, we give examples where free trade induces governments to set environmental policies that are tougher than the efficient one, and examples in which the opposite is true.

The fact that strategic trade considerations could make environmental policies tougher is not new. This is the first time, however, that this result is obtained in a situation in which tougher environmental policies imply higher unit costs for domestic firms and these increases

[2] This would not be exactly true if the marginal cost for the firm were not constant. In this case strategic considerations could be different under policy coordination than under decentralized policies.

the competitive pressure on domestic firms. The result is a consequence of the tradeoff between rent shifting and pollution export incentives in the presence o imperfect competition. Barrett (1994) has previously obtained that strategic trade considerations could make environmental policies tougher provided that either competition is in prices or there are enough firms in each country so that higher unit costs reduce competiton among domestic firms[4]. The reason is that in his model firms sell in a third country. That is, his is not a model of bilateral trade, but rather a model of trade competition in foreign markets. But, as follows directly from the discussion above, assuming away the consumer's surplus as part of the objective function for governments implies not taking into account one of the driving forces for our results: the use of the environmental instrument to approach willingness to pay to marginal social cost of production[5]. We show that this goal can make decentralized policies tougher than globally efficient ones even under quantity competition and one firm in each country.

Another possibility for trade distortions to induce tougher environmental policies has been pointed out by Ulph and Ulph (1995). As in Barrett (1994), they consider the interaction between two governments whose firms sell in a third country. Governments can set taxes on emissions which then induce firms to undertake R&D activities to cut emissions or reduce costs (process R&D). Whether governments set too high or too low taxes depends on the elasticity of R&D activities with respect to taxes. In case firms' increase in R&D is enough to offset the direct effect of an increase in taxes on the final unit cost of production, the effect of trade could be to increase the tax on emissions. In our paper, the effect of tougher environmental policies will always be to increase the unit cost of production of the domenstic firm. Thus, our results does not depend on induced indirect effects on these costs.

Also related to our work, Markusen, Morey and Olewiler (1995) do consider the incentives to export pollution: they also consider bilateral trade. The main difference is that they focus on the location problem faced by a single monopoly which can produce from either of the two countries, one country alone, or not produce at all. When the disutility of emissions is too large, they show that environmental policies (taxes) could be used with the purpose of exporting pollution. In this case both governments puts a tax large enough as to drive the monopoly from their country, and then no pollution or production takes place in either country. Our model, on the contrary, analyzes "interior solutions" in which production (and therefore pollution) takes place. Governments set high taxes even though their firms do compete with foreign firms. Finally, they do that even though their decisions do not change the market structure.

[4] This is in the same spirit as the results obtained in the classical paper by Eaton and Grossman (1986). Also, considering taxes on pollution, Conrad (1993) obtains that trade always induce weaker tax on polluting output since he considers quantity competition and one firm per country.

[5] A second best substitute for antitrust policy, as Eaton and Grossman (1986) put it.

The rest of the paper is structured as follows. Section 2 presents the general model and three more specific environmental policy instruments. Section 3 solves the model for firms' and governments' competition. Section 4 explores the first of our central questions: how bilateral reductions in tariffs affect the equilibrium environmental policies, and how free trade environmental policies compare to the ones obtaines under tariff competition. Section 5 deals with the comparison of environmental policies under trade with globally efficient ones. We conclude in Section 6.

2.-The model

Two firms, each located in a different country, produce an homogeneous, tradable good. The demand for this good in each country is given by the inverse demand function P(Q). We assume that this is a concave function. Also, we assume constant marginal cost of production, which we normalize to zero, and no fixed costs. Finally, firms compete in each market by setting quantities.

Local production generates local pollution as an external effect[6]. The level of this pollution is affected by environmental decisions of the governments that result in some costs for the firms. In order to simplify the analysis, we will assume that these costs will be always linear in production so that markets in both countries are separated. Thus, we assume that each government sets a variable c which results in a unit cost of production c for the domestic firm. Then, given c and the production q of the domestic firm, the cost of pollution (not born by the firm) is given by a function g(c,q). This function is assumed to be convex, increasing in q and decreasing in c. We will consider the following particular cases for this function g:

(i) Pollution standards: The function g takes the following functional form:

$$g(c,q) = A[(b-c)q]^2,$$

where A and b are two positive constants. This functional form represents the case in which there is a continuum $n \in [0,b]$ of possible, perfectly substitutable, inputs from which to produce the commodity q at constant returns to scale, where the index n is the (fixed, exogenously given) price of input n. The higher n, the lower the level of emissions of any given output q, represented by (b-n)q. Finally, the damage of emissions increases more than proportionally with its level, $A[(b-n)q]^2$. Thus, setting a standard is equivalent to setting the admissible maximal polluting (cheapest) input c, which the firm will actually choose to use. That gives our function g(c,q) above.

[6]The same features would be obtained under spill overs in pollution, as far as there is still a component of local pollution.

(ii) Pure tax on production: This is the case when governments cannot tax emissions directly, but can tax polluting production with a tax rate c. In this case

$$g(c,q) = - cq + h(q),$$

where h(q) is a convex, increasing function representing the damage/pollution caused by production q, and cq represents the tax revenue obtained by the government.

(iii) Tax on pollution with firms choosing technology: In this case the government can tax pollution directly, but firms can choose among several constant marginal cost technologies with different degrees of pollution. This is the model analyzed by Kennedy (1994). Governments set tax rates τ on emissions which are given by the function $Z(\theta,q) = q/\theta$, where θ represents the technology chosen by the firm after observing the government's choice of τ. Technology θ also results in unit costs θ. Hence, cheaper technology results in higher pollution. Emissions cause damage given by the increasing and convex function e(Z). In this model, profit maximization by a firm implies choosing $\theta = \tau^{1/2}$, independently from the level of production, so that the total cost for the firm is given by

$$\theta q + \tau Z(\theta,q) = 2\, \theta\, q.$$

Thus, letting $c = 2\theta$, Kennedy's model is a particular case of the model considered here with $g(c,q) = - \frac{c}{2} q + e(\frac{2}{c} q)$.

In the absence of a trade agreement, both governments simultaneously set their environmental policies and their trade policies which take the form of per unit tariffs t_i. After observing c and t in both countries, each firm perceives two separate markets. This is due to the assumption of constant production and environmental marginal costs at the firm level. Each firm decides how much to produce for each of the markets. Thus, for i = 1,2 we denote by q_i and q_i^* respectively the quantities produced by firm i for sale in its domestic (i) and foreign (j) markets.

The behavior expected from both governments and firms will be the (subgame perfect Nash) equilibrium of a two stage game. In the first stage, governments simultaneously set standards and, eventually, tariffs. In the second, firms set quantities. Firms are interested in maximizing profits, that is, revenue minus the cost incured due to the choice of c and t. Governments are interested in maximizing surplus minus environmental damages plus tariff revenue.

3.- Strategic interaction between trade and environmental policies

We start by analyzing the behavior of firms when there is an environmental policy c_i, $i = 1,2$ for production in country i and a tariff t_i on imports to country i. Firm i chooses q_i and q_i^* taking the productions of the rival firm j, q_j and q_j^* as given. Let $T = (t_1,t_2)$ and $C = (c_1,c_2)$. Then q_i is chosen to maximize

$$\pi_i(q_i,q_j^* \mid T,C) = P(q_i+q_j^*)\, q_i - c_i q_i \,.$$

On the other hand, q_j^* is chosen as to maximize

$$\pi_j^*\,(q_i,q_j^* \mid T,C) = P(q_i+q_j^*)\, q_j^* - (c_j+t_i)\, q_j^*.$$

The first order conditions for these two problems (market in country i) are given by

$$P'(q_i+q_j^*)\, q_i + P(q_i+q_j^*) - c_i = 0, \tag{1}$$

and

$$P'(q_i,q_j^*)\, q_j^* + P(q_i+q_j^*) - (c_j+t_i) = 0. \tag{2}$$

We assume that $\frac{\partial^2\pi_i}{\partial(q_i)^2} > \frac{\partial^2\pi_i}{\partial q_i \partial q_j^*}$ and $\frac{\partial^2\pi_j^*}{\partial(q_j^*)^2} > \frac{\partial^2\pi_j^*}{\partial q_i \partial q_j^*}$ in absolute value. This, together with concavity of the demand function, ensures existence and uniqueness (see for instance Tirole 1988).

Equation (2) defines q_j^* as a function of q_i, for given values of c_j and t_i, whereas equation (1), defines q_i as a function of q_j^*. The slopes of these reaction functions are negative and, given our assumptions, their absolute values are smaller than 1. Now, lowering t_i shifts the reaction function of firm j outwards (see Figure 1). That is, $\frac{\partial q_j^*}{\partial t_i} < 0$. Therefore, firm j becomes more aggresive and, as a consequence, the production of firm i is lower when t_i is lower. The traditional argument is that the government of country i will try to compensate for this increase in the competition faced by its firm by softening the environmental policies (reducing c_i).

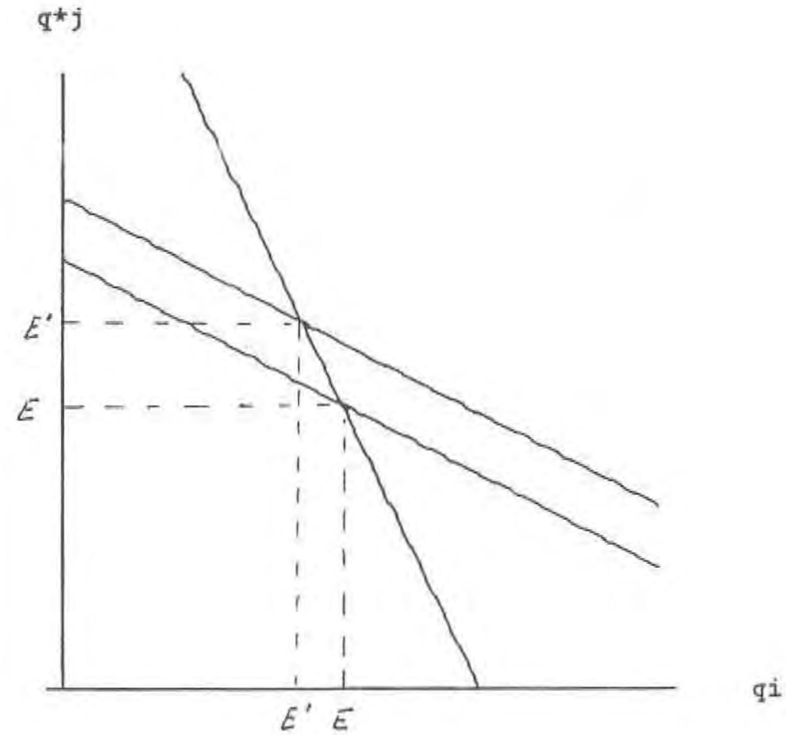

Figure 1

The effect of a reduction of t_i in market i

Things are different, however, if what is considered is a simultaneous reduction of both t_1 and t_2. The reduction of both tariffs has the effect on the market of country i already analyzed, but it also has a parallel effect on the market of country j. Therefore the competitiveness of firm i has decreased in its home country, but it has increased in country j. Let us assume for simplicity that we start from a symmetric situation, that is tariffs, environmental policies, and productions are the same in both countries. Then an equal reduction in both tariffs has also a symmetric effect on the productions of both firms. Graphically, the total effect in one country is represented in Figure 1 by the change from E to E'. Since the equilibrium is symmetric, the total production in a country coincides with the total production of one firm. Since the slope of the reaction function is samller than 1, we conclude that E' represents a larger total production. This, reducing both tariffs increases the total production of each firm.

Equations (1) and (2) and their equivalent equations for country j implicitly define the equilibrium productions as functions of C and T. In particular, markets are separated, and therefore q_i and q_j^* do not depend on t_j. Also, q_i and q_j^* only depend on (c_j+t_i) and c_i. Thus, we can write the solutions as $q_i(c_i,c_j+t_i)$ and $q_j^*(c_i,c_j+t_i)$.

Now we can analyze the first stage of the game, that is, the governments' competition on t and c. We assume the objective function for government of country i to include consumer surplus in the country and profits of firm i. It also includes any possible tariff revenue and the loss associated to emissions. Let $Q_i = q_i+q_j^*$. Thus, we can write this objective function as

$$W_i(C,T) = CS(Q_i) + t_i\, q_j^* + \pi_i[q_i,q_j^*] + \pi_i^*\, [q_j, q_i^*] - g(c_i, q_i+q_i^*)$$

where q_i and q_i^*, for i = 1,2, are defined by the equilibrium equations above and $g(c_i, q_i+q_i^*)$ are the total cost of emissions resulting from a domestic production of $q_i+q_i^*$ given c_i, and

$$CS(Q_i) = \int_0^{Q_i} [P(x) - P(Q_i)]dx.$$

Using equations (1) and (2), the first order conditions for this problem are

$$\frac{\partial W_i(C,T)}{\partial c_i} = CS'(Q_i)\,\frac{\partial Q_i}{\partial c_i} + [P'(Q_i)\, q_i + t_i\,]\,\frac{\partial q_j^*}{\partial c_i} +$$

$$+\ P'(Q_j)\, q_i^*\,\frac{\partial q_j}{\partial c_i} - (q_i + q_i^*) - g_1 - g_2\,[\,\frac{\partial(q_i+q_i^*)}{\partial c_i}\,] = 0, \qquad (3)$$

and

$$\frac{\partial W_i(C,T)}{\partial t_i} = CS'(Q_i)\,\frac{\partial Q_i}{\partial t_i} + q_j^* + [P'(Q_i)\, q_i + t_i\,]\,\frac{\partial q_j^*}{\partial t_i} - g_2\,\frac{\partial q_i}{\partial t_i} = 0. \qquad (4)$$

Equation (3) can be read as follows. When increasing c_i there is a change in the quantities sold in country i, which affects the consumer's surplus. Also, the foreign firm reacts by increasing its production for both the market in country i and j, since now the rival firm i is less competitive (first part of second term and third term in (3)). However, tariff revenue is enhanced (second part of second term in (3)). Another reduction in profits for firm i comes from the fact that its production $(q_i + q_i^*)$ is now more expensive (fourth term in (3)). Finally, emissions are affected for two reasons: first, the emissions per unit produced are affected, and second, the production by firm i is reduced as a consequence of the higher unit cost. Those are the two last terms. The optimal c_i balances all these effects.

It is important to realize that the last term is the reduction in pollution costs due to the reduction in national production. This could also be read as the pollution that is being exported to the foreign country. This illustrates the trade off between rent shifting and pollution exports already noted by Kennedy (1994).

Equation (4) has a similar explanation. Increasing t_i reduces the total supply in country i, and therefore the consumer surplus, but it reduces the imports, which results in lower tariff revenue. The increase in t_i has also a positive, direct effect on this revenue, of course. On the other hand, firm i's revenue increases as a consequence of the increase in price due to the reduction in imports. Finally, firm i's increase in production, due to the reduction in imports, means a higher level of emissions. This last effect can be understood as a reduction in the emissions exports. The optimal t_i balances all these effects.

4.-Tariff competition and free trade

We now turn to the central question of how the solution to (3) and (4) for i = 1,2 changes in the face of a free trade agreement by which both tariffs are set equal to 0. Let's start by analyzing how the solutions for c_1 and c_2 change as a consequence of equal (marginal) decreases in both t_1 and t_2. We therefore analyze equation (3) for different values of $T = t_1 = t_2$. Given T, equation (3) defines c_i as a function of c_j. By totally differenciating (3), the sign of the shift of this reaction function in face of an increase in t_1 and t_2 is given by

$$\frac{dc_i}{dT} = -\frac{\partial^2 W_i(C,T)/\partial c_i \partial t_1 + \partial^2 W_i(C,T)/\partial c_i \partial t_2}{\partial^2 W_i(C,T)/\partial c_i \partial c_i}.$$

Assuming a symmetric (and interior) equilibrium exists before and after the reduction in t, a sufficient condition for a decrease in t to induce a higher c_i in equilibrium is that $\text{sign}[\partial^2 W_i(C,T)/\partial c_i \partial t_1 + \partial^2 W_i(C,T)/\partial c_i \partial t_2] = \text{sign}[\partial^2 W_i(C,T)/\partial c_i \partial c_i]$. Indeed, in this case a decrease in T shifts the reaction function of each government outwards, and therefore the intersection of these reaction functions, always along the 45 degree line under symmetric equilibrium, takes place at a higher value of c_1 and c_2 (see Figure 2 for the case of upward sloping reaction functions). On the other hand, the second order conditions for the maximization of $W_i(C,T)$ with respect to c_i include that $\partial^2 W_i(C,T)/\partial c_i \partial c_i$, the derivative of the left hand side of (3) with respect to c_i, be negative. Therefore, the question is whether or not $\partial^2 W_i(C,T)/\partial c_i \partial t_1 + \partial^2 W_i(C,T)/\partial c_i \partial t_2 < 0$. The expression for this special cross derivative is given in the appendix, for the general case[7].

[7]Also, since the analysis provided above is marginal and based in a perturbation near the equilibrium point, it does not give a conclusive anwer as to the effect on environmental policies of a free trade agreement. This would anwer the question in cases where equilibrium tariffs are small. For other cases we need to calculate the policies corresponding to both regimes.

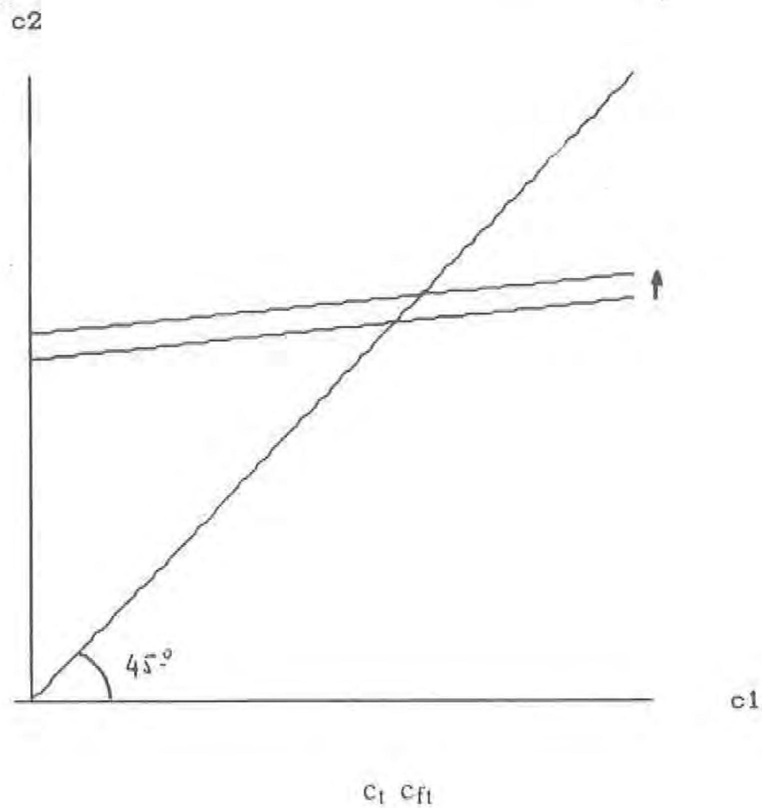

Figure 2

Effect on equilibrium of an increase in both t_1 and t_2

In order to better understand the factors affecting the sign of that expression, let's now concentrate on the linear demand case, $P(Q) = 1 - Q$. In this case, all the second order derivatives of quantities and prices vanish. Thus

$$\frac{\partial^2 W_i(C,T)}{\partial c_i \partial t_1} + \frac{\partial^2 W_i(C,T)}{\partial c_i \partial t_2} =$$

$$CS'' \frac{\partial Q_i}{\partial c_i} \frac{\partial Q_i}{\partial t_i} + [P' \frac{\partial q_i}{\partial t_i} + 1] \frac{\partial q_j^*}{\partial c_i} + P' \frac{\partial q_i^*}{\partial t_j} \frac{\partial q_j}{\partial c_i} - \frac{d}{dc}[\frac{\partial}{\partial q}(cq + g(c,q))] \frac{\partial Q_i}{\partial t_i}$$

where we have applied the symmetry assumption to substitute $\frac{\partial q_j^*}{\partial t_i}$ for $\frac{\partial q_i^*}{\partial t_j}$ and we have used $CS'' = - P'$. The first three terms in the above expression measure the effect of a change in t on the responsiveness (through the change in production) of consumer surplus and firm's and government's revenue to changes in c. All these terms are constant in the linear demand case and their sum is positive. The last term measures the responsiveness to c of the marginal social cost of production. Thus, the above expression can be written as

$$\frac{\partial^2 W_i(C,T)}{\partial c_i \partial t_1} + \frac{\partial^2 W_i(C,T)}{\partial c_i \partial t_2} = H - K[1 + g_{12} + C g_{22}], \tag{5}$$

where

$$H = P'[-\frac{\partial Q_i}{\partial c_i}\frac{\partial Q_i}{\partial t_i} + \frac{\partial q_i}{\partial t_i}\frac{\partial q_j^*}{\partial c_i} + \frac{\partial q_i^*}{\partial t_j}\frac{\partial q_j}{\partial c_i}] + \frac{\partial q_j^*}{\partial c_i} > 0,$$

$$K = \frac{\partial Q_i}{\partial t_i} < 0,$$

$$C = \frac{\partial(q_i + q_i^*)}{\partial c_i} < 0,$$

are all constants. Then, a simultaneous reduction (increase) in both tariffs increases (decreases) the equilibrium environmental protection <u>if the responsiveness of social marginal cost of production to changes in c is large and negative</u>. That is, if the reduction of the social marginal cost of production caused by a tougher environmental policy is large enough to outweight its negative effect on consumer surplus and firm's revenues. Next we study examples of cases (i), (ii), and (iii) above to show that indeed the sign of (5) could be positive or negative. With these examples we also show that this is not only true for marginal changes in tariffs, but also when switching from a tariff competition regime to a free trade one.

(i) <u>Pollution standards</u>: Consider $g(c,q) = A[(b-c)q]^2$. Under the linear demand function $P(Q) = 1 - Q$, equations (1) and (2) can be solved explicitly, so that , in this case $H = \frac{5}{9}$ and $K = -\frac{1}{3}$, while

$$\frac{d}{dc}[\frac{\partial}{\partial q}(cQ + g(c,Q))] = 1 - 4A(b-c)[Q + \frac{2}{3}(b-c)],$$

where $Q = (2-2c-t)/3$. First notice that

$$\frac{\partial^2 W_i(C,T)}{\partial c_i \partial t_i} = \frac{4}{9}[\frac{1}{4} + A(b-c)[3Q + 2(b-c)] > 0.$$

That means that a unilateral reduction in t_i from the tariff competition solution would induce a shift towards the origin of the reaction function of government i. That is, lower trade protection would induce a less strict environmental policy for the country. However, according to (5) above, bilateral (marginal) reductions in t would increase the environmental parameter c if and only if

$$\frac{5}{9} + \frac{1}{3}\{1 - 4A(b\text{-}c)[Q + \frac{2}{3}(b\text{-}c)]\} = \frac{4}{9}[2 - A(b\text{-}c)[3Q + 2(b\text{-}c)]],$$

which can be positive or negative. Indeed, letting $A = 10$ and $b = .2$ we obtain that under trade competition[8] (3) and (4) would result in tariffs $t = .203$ and standard $c = .0881$, with productions in both markets $Q = .54$ ($q = .371$ and $q^* = .169$) as the (unique) symmetric equilibrium. With these values, (5) is negative. That is, marginal reductions of tariffs imply higher levels of c. In fact, under free trade the standard would raise to $c = .0895$ with prices $Q = .606$. However, if we let $A = 10$ and $b = .8$, we obtain $t = .047$ and $c = .6273$ under trade competition, with $Q = 0.233$ ($q = 0.134$ and $q^* = 0.093$), and then (5) becomes positive, which means that marginal reductions in the tariffs imply a lower standard. Indeed, under free trade there is a decrease in standard to $c = .6265$, with $Q = 0.248$.

(ii) Pure tax on production: This is the case in which $g(c,q) = h(q) - cq$. Then,

$$\frac{d}{dc}[\frac{\partial}{\partial q}(cQ + g(c,Q))] = C\, h''(Q) = -\frac{4}{3}\, h''(Q),$$

and then (5) is simply

$$\frac{5}{9} + \frac{1}{3}[-\frac{4}{3}\, h''(Q)] = \frac{1}{9}[5 - 4h''(Q)].$$

Thus, whenever $h''(Q)$ is larger than $\frac{5}{4}$ at the equilibrium production Q for the domestic firm, a reduction in tariffs implies an increase in the tax on production.

As an example, consider $h(Q) = \frac{1}{3} Q^{3/2}$. Then we have that under tariff competition $c = .16$ and $t = .22$ with production $Q = .48$ ($q = .35$ $q^* = .13$). Then $h''(Q) = .35$, and thus a reduction in tariffs implies a lower tax on production. Indeed, under free trade $c = .09$ and $Q = .6$. On the other hand, if $h(Q) = \frac{2}{3} Q^3$, under tariff competition $c = .23$, and $t = .2$, with $Q = .44$ ($q = .32$, $q^* = .12$). Then $h''(Q) = 1.76$ and a marginal decrease in t would induce a higher tax on production. In fact, under free trade $c = \frac{1}{4}$, with $Q = \frac{1}{2}$.

(iii) Tax on pollution with firms choosing technology: Remember that this case is equivalent to assuming $g(c,q) = -\frac{c}{2}q + e(\frac{2}{c}q)$. Then

[8] Second order conditions can be checked to hold in this and all other cases considered.

$$\frac{d}{dc}\left[\frac{\partial}{\partial q}(cQ+g(c,Q))\right] = \frac{1}{2} - \frac{2}{c^2}\{e'(\frac{2}{c}Q) + e''(\frac{2}{c}Q)[\frac{8}{3}+\frac{2}{c}Q]\},$$

ınd (5) becomes

$$\frac{5}{9} + \frac{1}{6} - \frac{2}{3c^2}\{e'(\frac{2}{c}Q) + e''(\frac{2}{c}Q)[\frac{8}{3}+\frac{2}{c}Q]\}.$$

\gain, this expression can be positive or negative. For instance, let $e(x) = A\,x^{\lambda}$. Then, for A = 05 and $\lambda = 2$, we have that under free trade (3) results in c = .556, with Q = .296. At these 'alues (5) becomes negative (-.30). That is, a marginal tariff (more trade protection) would nduce a lower tax on emissions. Indeed, under tariff competition we have c = .548 and t = 127, with Q = .259 (q = .193 and q* = .066). However, for A = .01 and $\lambda = 3/2$ the olution to (3) under free trade is c = .257, with Q = .495. Then (5) takes a positive value .18), so that a marginal tariff induces a higher tax on emissions. Indeed, under tariff ompetition the solution to (3) and (4) gives c = .264 with t = .22 and Q = .417 (q = .31 and q* = .107).

The conclusion is that a decrease in both tariffs has ambiguous effects on the nvironmental policy. Depending on functional forms for g and the demand function, the effect ould be a tougher environmental policy or a weaker one.

:.-Social efficiency of environmental policies with trade

'or the moment assume there is no trade, there is only one firm in the country, and take the nost simple of our interpretation of g(c,q), that is, case (ii) above. If firms behave as price akers, a way to attain efficiency is by imposing a tax on production equal to the marginal social ost of emissions at the level where this marginal cost equals willingness to pay, that is, point E n Figure 3. Indeed, under price taking behavior, this tax, taken by firms as constant marginal ost, makes E the equilibrium production and this is the efficient level. This solution is haracterized by

$$P(E) = h'(E)$$

nd is attained by setting c = h'(E), the Pigouvian tax. However, when the firm has market ower this tax would result in a choice Q = D which equals marginal cost h'(E) with marginal evenue, P(D) + P'(D)D. That is, D < E. Thus, the government would have to set a tax c' ower than h'(E), in order to induce the firm to choose the (first best) production E. Thus, in rder to take care of the distortions due to market power, the government distorts the incentives or the firms. The question we study in this section is how this distortion changes in the face of 'ade, free or managed, and the direction of the change.

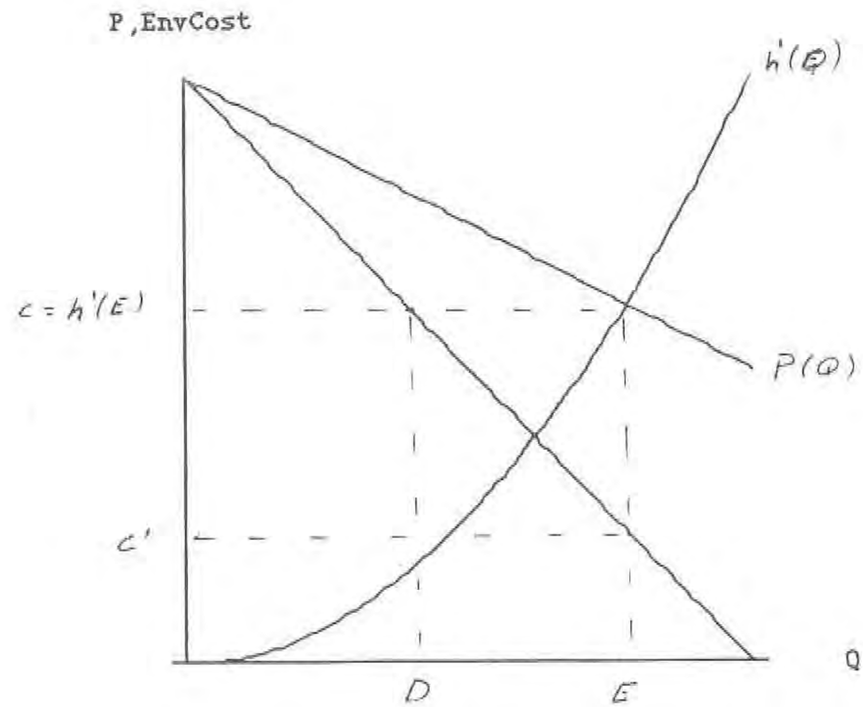

Figure 3

Efficient environmental tax in the one country-monopoly case

We start by analyzing the globally efficient environmental policiy taking into account the existence of market power by firms. This is characterized by the environmental policy that a planner (common to both countries) would impose in both countries. Since we are assuming constant returns to scale technologies and convex environmental damages, this solution would imply symmetric policies and therefore symmetric productions. Thus, we can concentrate on the situation of one of the countries to analyze this efficient policy. The problem for the planner would be

$$\max_{c} \int_0^Q P(x)\ dx - cQ - g(c,Q), \tag{6}$$

where Q would be both the quantitiy produced and the quantity consumed in one of the countries (equal, by symmetry), and c the common policy parameter. The first order condition for this problem is

$$[P(Q) - c - g_2] \frac{dQ}{dc} - Q - g_1 = 0. \tag{7}$$

where $\frac{dQ}{dc}$ is the change in production by two symmetric, competing firms, each one having costs c. Notice, in particular and contrary to the simple case of taxes on production considered above, that the solution to (7) needs not imply that the price is equal to the marginal social cost of production, $c + g_2$. The reason is that, in general, the instrument to make the firm internalize the environmental cost, has also a direct effect on emission costs, $Q + g_1$. Indeed, P could be higher than $c + g_2$ in the efficient solution (i.e., c could be higher than the one that would induce $P = c+g_2$) if an increase of c lowers social cost of the given output[9]. This fact will be crucial for the conclussions that follow.

Now, turn to the decentralized case. Add equation (3) to the left hand side of equation (1) multiplied by $\frac{\partial q_i}{\partial c_i}$ and the left hand side of equation (2) for firm i multiplied by $\frac{\partial q_i^*}{\partial c_i}$ (both equal to zero). Then $\frac{\partial W_i(C,T)}{\partial c_i}$ can be written as

$$\frac{\partial W_i(C,T)}{\partial c_i} = [P(Q_i) - c - g_2]\frac{\partial (q_i+q_i^*)}{\partial c_i} - (q_i + q_i^*) - g_1 - \qquad (8)$$
$$[P'(Q_i)\, q_j^* \frac{\partial Q_i}{\partial c_i} - P'(Q_j)\, q_i^* \frac{\partial Q_j}{\partial c_i} - t_i \frac{\partial q_j^*}{\partial c_i} + t_j \frac{\partial q_i^*}{\partial c_i}].$$

The first term on the right hand side represents the increase in the cost of imports for country i induced by an increase in c_i. The second term represents the corresponding decrease of exports revenues. In any symmetric situation with no tariffs, these two terms are equal, since firms are then symmetric in both markets. Therefore (8) becomes

$$\frac{\partial W_i(C,T)}{\partial c_i} = [P(Q_i) - c - g_2]\frac{\partial (q_i+q_i^*)}{\partial c_i} - Q_i - g_1 \qquad (9)$$

The difference between the left hand side of (7) and the right hand side of (9) is that we have $\frac{dQ}{dc}$ in (7) and $\frac{\partial (q_i+q_i^*)}{\partial c_i}$ in (9). The first term is the response of the production of two competing firms to increases in their respective marginal costs. The second term is the response of the production of two firms faced with an increase in their marginal costs when each is competing with another firm whose costs do not change. Then, we would expect $\frac{dQ}{dc}$ to be

[9] That is, if an increase in c increases the production costs of the given output by less than it reduces the externality costs of this output, so that $Q + g_1 < 0$.

smaller in absolute terms than $\frac{\partial(q_i+q_i^*)}{\partial c_i}$, though they may be evaluated at different levels of production. This is certainly the case when the demand is linear, since then neither derivative depends on the level of production. This also shows the origin of the distortion introduced by strategic interaction among governments: the reaction of domestic production to changes in c is larger than when the level of c is set by a global government.

Kennedy (1994) has analyzed the direction of this distortion looking at $\frac{\partial W_i(C,T)}{\partial c_i}$ when evaluated at the globally efficient levels of environmental protection. If this derivative is negative, the governments would react to policy competition by decreasing the levels of environmental protection. Thus, in equilibirum we would expect less environmental protection than the globally efficient one. He also shows that, in the model he considers, that derivative is actually negative. This, however, is only a consequence of the particular functional forms that he chooses for the function g. Indeed, equation (9) shows that the total effect of an increase in c is composed of two parts: the direct effect on social cost of production, $Q + g_1$, and the indirect effect on net surplus (consumer's surplus minus social cost) through the change in domestic production[10]. At the efficient solution (see equation (7)), the first effect is balanced against the indirect effect of a change of c <u>through the change in production of two firms both of whose costs increase.</u> Therefore, the direct effect in (9) is weaker than the indirect effect. That is, evaluating equation (9) at the (symmetric) efficient levels of c, C^*, and substituting $Q + g_1$ using equation (7), we have that

$$\frac{\partial W_i(C^*,0)}{\partial c_i} = [P(Q) - c - g_2]\,[\frac{\partial(q_i+q_i^*)}{\partial c_i} - \frac{dQ}{dc}], \tag{10}$$

and, since $[\frac{\partial(q_i+q_i^*)}{\partial c_i} - \frac{dQ}{dc}] < 0$, (10) is negative if and only if $[P(Q) - c - g_2] > 0$. That is, as we mentioned above, if and only if $Q + g_1 < 0$. The reason is that, since output response is higher under policy competiton, reducing c increases the consumption in the country by more than under coordination. If the marginal willingness to pay is higher than social marginal cost of production, this higher increase is positive for the country, more than outweighting the negative direct effect on social cost of the given output. But the opposite would be true if marginal willingness to pay were lower than marginal social cost of production.

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[10] Indeed, although the increase in consumer's surplus is directly realized by the country through the increase in domestic production of the firm directed to the domestic market, profit maximization of the domestic firm in the foreign market internalizes the increase in consumer surplus of foreign consumers. This is so because q_i^* is taken to the level at which $P - c = - P'q_i^*$.

Again, which of the two cases is the one faced by the governments depends on the particular functional forms of the model. Kennedy (1994) obtains that $\frac{\partial W_i(C^*,0)}{\partial c_i}$ is always negative simply because under the particular family of functional forms[11] he works with $[P(Q) - c - g_2] > 0$.

In general, however, this needs not be true. We have already seen that in the tax on production case (case (i)), $Q_i + g_1 = 0$, i.e. $[P(Q) - c - g_2] = 0$ from equation (7), and so (10) = 0. That is, free trade would ensure the efficient level of environmental protection (tax on production)[12]. Moreover, in case (i) (the standards case), (10) is negative for some values of the parameters and positive for others. Indeed, for A = 10 and b = .2 the solution to (7) above is c = .1, with production Q = .6, which means that the globally efficient level of c is higher than the free trade one, c = .0895 (and indeed, in this case $[P(Q) - c - g_2] = .18$ at the efficient solution). But for A = 10, b = .8, the solution to (7) has c = .621, with Q = .26, which means that the globally efficient level of c is lower than the free trade level, c = .6265 (and indeed, in this case $[P(Q) - c - g_2] = -.05$ at the efficient solution).

When there is tariff competition, the effect on a change in c has an additional term, $t_i \frac{\partial q_j^*}{\partial c_i} - t_j \frac{\partial q_i^*}{\partial c_i}$, which is positive. These terms represent the additional distortion introduced by the incentives of governments to reduce the tariff revenue paid by the domestic firm to the foreign country and the incentive to increase the tariff revenue it obtains from the foreign firm. Again, in case $[P(Q) - c - g_2] > 0$, this implies an additional distortion towards reducing c from the optimal (symmetric in terms of production) solution, but the opposite is true when $[P(Q) - c - g_2] < 0$. The examples given for the case (i) indeed shows that the distortion can take either of the two directions.

The conclusion is that under bilateral trade and market power conditions, the incentives of governments to set tough environmental policies need not be weak, as compared to the efficient, coordinated solution. Whether this is the case or not depends crucially on the interplay of direct effects of c on emissions and its indirect effect through the production choices of firms.

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[1] Indeed, with the functional forms chosen by Kennedy adapted to our case, we have that $Q + g_1 = Q[1 - \frac{c+g_2}{c}]$ $= - Q\frac{g_2}{c} < 0$, and then, since $\frac{dQ}{dc} < 0$, (7) implies that $[P(Q) - c - g_2] > 0$.

[2] The results obtained by Hung seem to contradict our results. The explanation, we think, is a mistake in one f the proofs by Hung.

6.-Concluding remarks

In this paper we have analyzed the effects of trade on environmental policies in a world of bilateral trade and market power by firms. We have studied particular forms that environmental policies can take: pollution standards, production taxation, and emissions taxation when firms can choose among different technologies. We were concerned with two central questions. The first is to compare environmental policies before and after a free trade agreement is signed. We have identified the situation before the agreement as one in which governments can set tariffs on imports non cooperatively. Thus, we compared the strategic interaction of governments when they can influence production and pollution with two instruments, tariffs and environmental variables (standards, taxes on production, or taxes on emissions), with the interaction when they can only use environmental policies. The sign of the change in the environmental variable following the abolition of tariffs can take either direction, leading to tougher or weaker environmental policies. Weaker policies can be expected when the effect of environmental protection on the marginal social cost of production is not large. However, if this effect is large and negative enough, the reduction in tariffs resulting from a free trade agreement will give rise to tougher environmental policies.

The second question was the characterization, from the global efficiency point of view, of equilibrium policies under both regimes. Governments equate costs and benefits of environmental policies, taking into account strategic considerations. Under free trade and symmetry, we have shown that the strategic distortions that appear are represented by the higher responsiveness of production to changes in the environmental policy as compared to what we would have under environmental policy coordination. The sign of this distortion on environmental policies depends on the interplay between the use of the environmental policies as an instrument to make firms internalize the environmental costs of production and its direct use as an instrument to regulate the total social cost of production. As a consequence of this latter use, total output under policy coordination (the efficient solution) counld be higher than the one that equals marginal willingness to pay with marginal social cost of production. If this is the case, policy competition would induce a tougher environmental policy. Otherwise, policies softer than effcient would result. We have shown examples of both types.

There is a case, in particular, in which the environmental policies coincide in both regimes. This is the case in which the environmental policy available to the government is simply a tax on production. In this case, the environmental instrument has no direct effect on the social cost of production (it is only a transfer form the firm to the government). Then the interaction of governments under free trade results in the global efficient level of production.

The entire analysis has been carried out under the assumption of symmetric firms and countries. We consider that an important question that remains open is the effect of free trade between asymmetric countries. It is important to understand the characteristics of the countries (size of markets, differences in costs of emissions or costs of production, difference in market structure,...) that will determine the direction of these effects, and the final allocation of production and pollution.

Appendix

From (3), taking derivatives with respect to t_i and t_j, we have:

$$\frac{\partial^2 W_i(C,T)}{\partial c_i \partial T} = CS''(Q_i)\frac{\partial Q_i}{\partial c_i}\frac{\partial Q_i}{\partial t_i} + CS'(Q_i)\frac{\partial^2 Q_i}{\partial c_i \partial t_i} +$$

$$[P'(Q_i)\, q_i + t_i\,]\frac{\partial^2 q_j^*}{\partial c_i \partial t_i} + [P''(Q_i)\frac{\partial Q_i}{\partial t_i}\, q_i + P'(Q_i)\frac{\partial q_i}{\partial t_i} + 1]\frac{\partial q_j^*}{\partial c_i} +$$

$$P'(Q_j)\, q_i^*\frac{\partial^2 q_j}{\partial c_i \partial t_j} + [P''(Q_j)\frac{\partial Q_j}{\partial t_j}\, q_i^* + P'(Q_j)\frac{\partial q_i^*}{\partial t_j}]\frac{\partial q_j}{\partial c_i} -$$

$$[\frac{\partial q_i}{\partial t_i} + \frac{\partial q_i^*}{\partial t_j}] - \frac{\partial^2 g}{\partial c_i \partial T}$$

where

$$\frac{\partial^2 g}{\partial c_i \partial T} = [g_{12} + g_{22}\frac{\partial (q_i + q_i^*)}{\partial c_i}][\frac{\partial q_i}{\partial t_i} + \frac{\partial q_i^*}{\partial t_j}] + g_2\,[\frac{\partial^2 q_i}{\partial c_i \partial t_i} + \frac{\partial^2 q_i^*}{\partial c_i \partial t_j}].$$

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