Can R&D-Inducing Green Tariffs Replace International Environmental Regulations?

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Summary

This paper investigates the link between trade and environment by exploring the effects of green tariffs on the location of firms, innovation and the environment. It shows that tariffs levied on polluting goods could result in less global pollution than harmonization of environmental standards by inducing more pollution abatement R&D, generating lower unit emissions from production, and reducing competition. Green tariffs reduce pollution by (1) shifting production to the region where environmental standards are respected, (2) strategically inducing abatement R&D by the Northern firm by granting the latter a higher market share, (3) creating abatement R&D by deterring delocation.

Keywords: Environmental Standards, Multinationals, Location of Firms, Pollution Abatement R&D, Green Tariffs

JEL Classification: F13, F18, F23, H23, Q21, R38

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1. Introduction

The link between trade liberalization and environmental protection is becoming more prominent in policy discussions with the latter constituting a bigger part of WTO rounds in recent years. The primary debate led by environmentalists is that trade liberalization damages the environment. This may occur as trade can increase pollution by increasing activity, i.e. opening the domestic market to or expanding the production of goods that are manufactured with environmentally unfriendly technologies. They argue that trade liberalization must be accompanied by policies aimed at harmonizing international environmental standards to prevent governments from distorting their environmental policies to protect their domestic economy. The lack of environmental restrictions has also been blamed for causing domestic firms to relocate plants abroad or close down home operations altogether to take advantage of lower production costs.[1] Nevertheless, it is not clear whether harmonized standards bring the results desired by environmentalists when paired with trade liberalization.

In an era of trade liberalization, failure to reach environmental targets due to a lack of participation in international environmental agreements has also led to calls for harmonized environmental regulations across countries. WTO involvement has been proposed to oversee trade and environment issues by granting a country that has adopted stricter environmental standards the option to only accept greater economic integration with another country if the latter also agrees to adopt tougher environmental policies. Alternatively, punishing tariffs have been suggested upon non-compliance on imports from countries with laxer environmental regulations. Does the harmonization of environmental standards necessarily work to improve the environment? Can tariffs be justified as an alternative green instrument to reach environmental targets, and if so, can they outperform environmental harmonization?

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[1] Empirical evidence has however found little or no strong evidence that stronger environmental regulation at home per se leads to delocation. See for example Beghin et al. (1994), Smarzynska and Wei (2001), Eskeland and Harrison (2003) and Grether and Melo (2003).

When discussing a cleaner environment and sustainable development, two basic issues come into mind: the decision of firms on where to locate and how much to invest in pollution abatement R&D. Zannetti and Abate (1993) have carried out a business survey to find that big corporations in industrialized countries indeed tend to respond to environmental policy measures primarily by technological and organizational innovation, and secondarily by re-localizing of plants and production. This has created two important branches of literature in environmental economics that study different aspects of the connection between each of these factors and environmental policy.[2]

Markusen, et al. (1993) was the first paper to investigate the relationship between firm location and environmental policy. In their model, the world is composed of two countries and two "footloose" firms. Firms decide where to set up production by observing the plant and firm specific fixed costs, transport costs and environmental policy in the two regions. They could decide not to enter the market at all, serve both regions from a plant at home, or establish plants in both regions to serve each market locally. They show environmental policy to have a very strong impact on a firm's decision about location. Motta and Thisse (1994) consider a different setting where firms are initially established in their country of origin and do not incur any fixed cost when operating at home. They examine the impact of a country's environmental policy on the location and production choices of its firm.[3] They show that a firm is less likely to relocate as a response to environmental policies because fixed costs of establishing a domestic plant are sunk when the game begins.

On the innovation side, Michael Porter (1991) pioneered the conception of positive externalities being generated by environmental regulation on R&D. He pointed out that environmental policies could spur domestic industries to develop greener technologies ahead

[2] For a survey of traditional and strategic literature on trade and environment see Neary (1999).

[3] In their model they also give the multinational firm the choice of closing down home production altogether and establishing a plant abroad to serve both markets. Additionally, they assume the other firm to be a local firm with its location (as well as the other country's policy) as given.

of their rivals to enhance long-run profitability through this so-called competitive advantage. The idea did not live long as several arguments emerged to confront Porter's hypothesis. One argument states that although environmental regulation can motivate innovation of better products or cheaper processes, it is not clear if the benefits will cover the costs of investments made in the necessary R&D. Simpson and Bradford (1996) for instance use this argument to challenge Porter by showing the two effects of tougher environmental policies on profits: the direct effect of increased production costs and the indirect effect of lower variable costs caused by the spurred innovation. They conclude that environmental regulation is unlikely to serve industrial advantage.

While in the field of environmental economics much work has been devoted to the two fields of location and R&D, no attempt has been made to show the effects of environmental policies on the two issues in a single framework. This paper brings economic integration (trade liberalization), environmental harmonization, firm location and pollution abatement R&D into one model to investigate how they interact to shape the environment.

The paper builds a two-country model with asymmetric environmental standards to show whether green tariffs or the harmonization of environmental standards spurs more efforts in pollution abatement R&D and leads to a cleaner environment. Green tariffs trivially shift production to the region, where environmental standards are respected. This move however increases the market share of the Northern firm and induces the latter to engage in more intensive pollution abatement R&D. It will also be seen that although trade liberalization does not necessarily lead to delocation, green tariffs can eliminate the attractiveness of delocation and encourage firms to use R&D as an alternative to reduce costs. Lower unit emissions from production and reduced competition result in higher pollution abatement R&D and less global pollution with green tariffs, raising doubts on the effectiveness of a dual policy of environmental harmonization and trade liberalization.

The Northern firm chooses production location in the first stage. Firms then decide how much to invest in pollution abatement R&D in the second stage and compete in production in the final stage. The model is suited to analyze the two aspects of the Doha proposal with regards to multilateral environmental agreements (MEA) and trade obligations: (1) Allowing a signatory country to impose green tariffs on a non-signatory by depriving the latter from its WTO rights (section 2); (2) making compliance with a MEA a precondition for WTO membership and benefits, i.e. economic integration accompanied by environmental harmonization (section 3). The model can be used to compare the implications of each proposal on pollution abatement R&D and the environment. The paper is organized as follows: Section 2 describes the model and solves the three stages of the game with green tariffs and no environmental standards enforced in the South. Section 3 introduces standards and shows firms' decision on output, R&D and location in the case of harmonized standards and liberalized trade. Section 4 looks at environmental gains from each regime, to find out how green tariffs compare to a mixed policy of environmental harmonization and free trade. Section 5 concludes.

2. The Model

There are two regions in the model: the North and the South. The North is assumed to enforce environmental standards through a tax on emissions released from production. The South in contrast has no environmental restrictions. Local as well as foreign firms can produce in the South with no extra costs for causing pollution. The model assumes two firms, one belonging to each region. They produce a homogeneous good and compete in an oligopolistic manner à la Cournot.[4] They compete in segmented markets and choose the optimal output for each market separately. Firms producing in the South are subject to a punishing 'green' tariff set on *all* dirty imports from the South, including re-exports of the Northern firm.[5] Firms are also capable of investing in pollution-abatement R&D to innovate cleaner production technologies and reduce their expenses on pollution tax.

[4] The model only considers goods that are directly related to environmental problems.

[5] We refrain from other forms of trade costs in order to focus on policy instruments directed at the environment. All key results hold if bilateral trade costs are introduced. One way would be to hold the latter fixed and study changes in environmental policy tools such as green tariffs and emission tax.

The Northern firm is a multinational and can choose its production location. It can stay at home and serve both markets from its Northern headquarters. It can also build a subsidiary in the South to have local access to the Southern market, but maintain domestic production for serving its home consumers. It can also close down home production altogether and delocate to serve both markets from the South. The Southern firm is assumed to be a local firm and only produces domestically.[6]

Demand is assumed to be linear and takes the familiar form

$$p_i = a - Q_i \tag{1}$$

for i=N, S, where Q is the total consumption in each region, and subscripts N and S represent the North and the South. Total consumption in each region is

$$Q_i^j = q_{ii} + q_{ik} \tag{2}$$

for i=N, S; $k \neq i$; and j=E, F, D. The first subscript indicates the identity of the producer, while the second denotes the intended market. Superscript E represents the case where the firm produces only in the North and exports to the South, F when it undertakes FDI to serve the Southern market locally, and D when it completely delocates production and re-exports back to the North. The costs of production are divided between a non-pollution related production cost c, which is assumed constant over firms and scales, and a unit pollution tax τ paid on emissions released from producing one unit of the good. The latter can be written as

$$e_i = e_0 - \sqrt{x_i} \tag{3}$$

for i=N, S, where $x \leq e_0^2$. Parameter e_0 represents the basic unit emission prior to any pollution abatement research, and x is the amount of R&D expenditure undertaken to innovate cleaner technologies. R&D expenditure the form of a one-time investment and reduces

[6] This framework is similar to one used in a study by Motta and Thisse (1994) to show that a firm's decision to relocate in case of economic integration is influenced by the relative marginal cost of production between the regions, the cost of relocation, the cost of exporting its good across borders and the relative size of the two regions.

emissions at a decreasing rate.[7] The initial abatement of the dirtiest part of production requires less expenditure than efforts to further improve an already greener technology.

The profit function for the Northern firm when all of its production takes place in the North is

$$\pi_N{}^E = q_{NN}(a - Q_N^E - c - \tau e_N) + q_{NS}(a - Q_S^E - c - \tau e_N) - x_N \,. \tag{4a}$$

This entails that the Northern firm pays a pollution tax on its entire production. When the firm builds a subsidiary in the South, it only pays a pollution tax on the goods it produces at home for its domestic market:

$$\pi_N{}^F = q_{NN}(a - Q_N^F - c - \tau e_N) + q_{NS}(a - Q_S^F - c) - x_N - \Gamma \,. \tag{4b}$$

Parameter Γ represents the fixed cost of setting up a plant abroad which is independent of output. If the firm completely delocates production to the South, it avoids paying a pollution tax, but is bound to pay a green tariff on its exports back to the North:

$$\pi_N{}^D = q_{NN}(a - Q_N^D - c - t) + q_{NS}(a - Q_S^D - c) - x_N - \Gamma \,. \tag{4c}$$

The profits of the Southern firm are

$$\pi_S{}^j = q_{SN}(a - Q_N^j - c - t) + q_{SS}(a - Q_S^j - c) - x_S \tag{5}$$

for *j=E*, *F*, *D*, depending on the Northern firm's decision on production location. Recall that no environmental tax is enforced in the South, but a tariff is paid on exports to the North under all circumstances.[8] Adopting backward induction, section 2.1 first solves the problem of firms in the final stage where they compete in output.

2.1. Production

In the export scenario where the multinational only produces at home, production by the two firms for the Northern and the Southern market are

$$q_{NN}^E = \frac{1 + t - 2\tau e_N}{3}, \qquad q_{SN}^E = \frac{1 - 2t + \tau e_N}{3},$$
$$q_{NS}^E = \frac{1 - 2\tau e_N}{3} \qquad q_{SS}^E = \frac{1 + \tau e_N}{3}. \tag{6a}$$

[7] The cost function containing pollution abatement R&D follows the approach used in Ulph (1994).

[8] t and τ have been normalized to the market size to eliminate *(a-c)* from all upcoming equations.

Under FDI, the Northern firm maintains domestic production for its home market and also serves the South through a local subsidiary. Output by each firm turns to

$$q_{NN}^{F} = \frac{1 + t - 2\tau e_N}{3}, \qquad q_{SN}^{F} = \frac{1 - 2t + \tau e_N}{3},$$
$$q_{NS}^{F} = q_{SS}^{F} = \frac{1}{3}, \tag{6b}$$

for the North and the South respectively. In the case of delocation, all production takes place in the South. This changes production by both firms to

$$q_{NN}^{D} = q_{SN}^{D} = \frac{1 - t}{3},$$
$$q_{NS}^{D} = q_{SS}^{D} = \frac{1}{3}, \tag{6c}$$

for each market. If the Northern firm produces at home for the domestic market, green tariffs lower imports from the South and increase local production in the North. Strategic interaction hence shifts production to the region where environmental standards are respected. Stricter (Northern) standards per se have the reverse effect of reducing Northern production and thereby encouraging production by the Southern firm. When the Northern firm exports to the South, τ affects the entire production by both firms, whereas with FDI only goods targeted at the Northern market are influenced. Since both firms produce locally for the Southern market under FDI, they face no pollution tax. Thus, their optimal quantity produced resembles that of a typical Cournot case. Finally, if the firm completely closes down production in the North and establishes a plant in the South to serve both markets, pollution tax becomes irrelevant and green tariffs reduce the exports of both firms to the North. No firm enjoys a production cost advantage in this case and the quantity produced by both firms is always equal.

Result 1

A green tariff discourages dirty imports from the South. Under exports and FDI, this expands production by the Northern firm for its home market. Production hence shifts from a 'dirty' South to a 'clean' North, where environmental measures are respected. A unilateral pollution tax in the North has the opposite effect.

2.2. R&D Investment

In the second stage, firms decide their R&D expenditure aimed at reducing emissions and cutting costs of production. Replacing the optimal outputs back into the corresponding profit functions and differentiating the latter with respect to x yields the optimal amount of R&D investment. If the multinational keeps all production at home, optimal R&D investment is

$$x^E = \left[\frac{2\tau(2+t-4\tau e_0)}{9-8\tau^2}\right]^2, \qquad (7a)$$

where the condition $t > 2(2\tau e_0 - 1)$ must hold for R&D investment to take place. When the Northern firm partly moves production to the South, it invests

$$x^F = \left[\frac{2\tau(1+t-2\tau e_0)}{9-4\tau^2}\right]^2 \qquad (7b)$$

in R&D, where a more relaxed constraint $t > 2\tau e_0 - 1$ is required for positive R&D. Finally,

$$x_N{}^D = 0 \qquad (7c)$$

as no R&D is undertaken if the Northern firm moves all production to the South to fully exploit the lack of environmental regulations. Similarly, the Southern firm never engages in pollution abatement ($x_S{}^j=0$) as there are no R&D incentives in the absence of a Southern pollution tax.

For industries that are not pollution intensive, R&D expenditure in the North has a monotonic increasing relation to the pollution tax because abatement is not costly and τ only has a marginal effect on production. For more pollution intensive industries, R&D has an inverted U-shape relation with τ. The pollution tax stimulates R&D, but also dampens production, which eventually overwhelms its encouragement of efforts to create a cleaner technology.

Green tariffs affect R&D investment through output for the Northern market, i.e. q_{NN} and q_{SN}. Since only imports from the South are subject to a green tariff, output for the Southern market (q_{NS} and q_{SS}) is always independent of t. Derivatives $\frac{\partial x_N{}^E}{\partial t} > 0$ and $\frac{\partial x_N{}^F}{\partial t} > 0$ show that green tariffs always induce R&D efforts to innovate more environmentally friendly technologies. This is because green tariffs discourage dirty imports by the Southern firm (q_{SN}), and boost local production (q_{NN}). A higher scale of production creates incentives for the Northern firm to make a larger one-time R&D investment to innovate a cleaner technology and cut the marginal costs of production (pay less emission tax). Green tariffs are inconsequential for R&D under delocation. It will be seen in the next section however, that a move from delocation to either FDI or export has an R&D creating effect by making R&D expenditure by the Northern firm positive.

Result 2

With exports and FDI, a higher scale of production in the North brought about by green tariffs induces the Northern firm to make a larger investment in abatement R&D to cut its expenses on pollution tax.

2.3. Location

In the first stage of the game, the Northern multinational must choose a location for serving each market. By substituting the optimal R&D investment back into the quantities produced and the Northern firm's profit functions, we can derive optimal profits for each case and compare them to find the locational outcome that yields the highest gains. Northern profits for each scenario are

$$\pi_N^E = \frac{81(1-2\tau e_0)^2 + 81(1-2\tau e_0 + t)^2 - 8\tau^2 t^2 (9-4\tau^2) - 36\tau^2 (2[1-2\tau e_0] + t)^2}{9(9-8\tau^2)^2}, \tag{8a}$$

$$\pi_N^F = \frac{9(1-2\tau e_0 + t)^2 + (9-4\tau^2)}{9(9-4\tau^2)} - \Gamma, \tag{8b}$$

$$\pi_N^D = \frac{2(1-t) + t^2}{9} - \Gamma. \tag{8c}$$

Under exporting, pollution standards in the North must be under a critical value $\tau < \frac{3(\sqrt{9e_0^{\,2} + 4t[1+t]} - 3e_0)}{4t}$ for the Northern firm to produce at home for the domestic market. Also, $\tau < \frac{3(3e_0 - \sqrt{9e_0^{\,2} - 4t})}{4t}$ must hold for the Northern firm to continue exporting to the South. The Southern firm on the other hand faces prohibitive tariffs $t < \frac{3[3(1+\tau e_0) - 4\tau^2]}{2(9-7\tau^2)}$ above which it ceases exporting to the North. Comparing profits when the Northern firm keeps all production at home with that of establishing an extra plant in the South, we can see that in the absence of relocation costs it would always be better off with the latter choice. Recall that FDI only differs from exporting in that it avoids pollution costs on the part of production that is intended for the Southern market.[9] Therefore, exporting here would only occur if plant-specific fixed costs, or other fixed costs such as inflexible foreign investment laws in the host country or political instability in the region are high enough to deter relocation ($\pi_N^E \geq \pi_N^F$); namely, when

$$\Gamma \geq \frac{4\tau(8\tau^3 - 4t^2\tau^3 + 36t\tau^2 e_0 - 18t\tau - 27\tau - 81\tau e_0{}^2 + 81e_0)}{9(9-4\tau^2)(9-8\tau^2)}.$$

Adding trade costs to the model only affects the exporting scenario and the dividing line between the latter and FDI. Clearly, trade costs reduce the likelihood of exporting, making it only profitable for low levels of trade costs.[10]

Comparing profits under FDI and complete delocation next to see the preferred mode of relocating production abroad, it is easy to see that a higher pollution tax in the North makes delocation more attractive. The threshold green tariff rate below which the multinational completely delocates is the *t* that makes profits under the two options equal ($\pi_N^F = \pi_N^D$):

$$\bar{t} = 1 - \frac{3}{2\tau^2}(1-\tau e_0)(3-\sqrt{9-4\tau^2}). \quad (9)$$

[9] This refers back to a line of literature on environment and firms' location pioneered by Markusen et al. (1993) that assumes firms to be footloose. Thus, there are no extra costs for relocation as they incur a plant specific fixed cost regardless of whether they build a plant at home or in the other region. The number of plants would however matter in determining the total fixed costs in their analysis.

[10] The dividing line between the export and the FDI case has been studied in Motta and Thisse (1994). It plays a more important role in their analysis, as they focus on differences in the market size between regions and in fixed costs of establishing a plant.

When the Northern firm has a plant in each region, a pollution tax under $\tau < \frac{1+t}{2e_0}$ is a necessary condition for $q_{NN}^F \geq 0$ to hold. A higher pollution tax in the North gives the Southern firm such a large competitive advantage that the Northern firm no longer finds it profitable to serve its home market and closes down home production altogether.[11] The green tariff must also be lower than $t < \frac{3(1+\tau e_0) - 2\tau^2}{2(3-\tau^2)}$ for the Southern firm to maintain its exports to the North, i.e. for $q_{SN}^F \geq 0$. This threshold value of t stops the importation of all dirty products to the North by blocking trade, and gives the Northern firm a monopoly position in its home market.[12] As green tariffs rise, delocation becomes less attractive for a larger range of Northern pollution tax. In other words, $\frac{\partial \bar{t}}{\partial \tau} > 0$ implies that tougher standards in the North require a higher green tariff on dirty goods from the South to impede delocation. Such punishing tariffs hence can be deemed 'green' for a third reason that they discourage delocation to pollution havens, which in turn induces a positive investment in pollution abatement R&D (as opposed to zero) by the Northern firm. Finally, the lower is the pollution intensity of the industry, the lower are the incentives to delocate. This is because a lower green tariff would be required for the Northern firm to break even with FDI. Furthermore, it is not worthwhile moving all production to the South and pay tariffs on re-exports back to the North when pollution expenses at home are not so high.

Figure 1 shows the location decision of the Northern multinational in the presence of positive fixed costs for a pollution intensity level of $e_0=1$. It can be seen that exporting is the mode of choice for serving the South when pollution tax in the North is sufficiently low. The figure shows a case, where $\Gamma = 0.05$. A higher (lower) fixed cost of relocation simply expands (shrinks) the export region. A high emission tax at home tempts the Northern firm to relocate

[11] This case coincides with the scenario of complete delocation.

[12] Such prohibitive tariff rates denote a complete ban on imports from the South making values of t above this level irrelevant for the analysis.

production to the South. For low enough levels of green tariffs ($t < \bar{t}$) the Northern firm completely delocates, whereas for a higher *t* it builds a subsidiary to serve each market locally to jump the pollution tax and avoid green tariffs.[13] A larger e_0 shifts the cone within which both firms have positive production to the left, while a smaller e_0 lowers it to the right. This is because costs related to higher pollution intensity makes it more difficult for the Northern firm to maintain production at home. On the other hand, the South enjoys a lower cost advantage in cleaner industries. Therefore the tariff rate that keeps the Southern firm out of the market is lower for smaller values of e_0. Lower pollution intensity also tilts the $\bar{t}$ curve downwards, making FDI preferable to delocation for a larger range of τ.

Note that trade liberalization, even in the absence of environmental harmonization, does not necessarily cause delocation to pollution havens. This is true as long as the fixed costs of relocation are positive. Such fixed costs induce the multinational to instead keep all production at home and export. This is indeed the case for low enough values of τ implying that delocation only occurs when the environmental tax in the North exceeds a critical level.

Result 3

Green tariffs discourage delocation to pollution havens. This compels the Northern firm to pay the home pollution tax, which in turn creates a positive R&D effort for abatement. A complementary green tariff policy can accompany an emission tax to prevent delocation.

3. Environmental Harmonization and Trade Liberalization

This section of the paper analyzes the consequences of policies that suggest global harmonization of environmental regulations. This can be interpreted as policies discussed in the WTO Doha round to make economic integration conditional upon MEA compliance. Here the South upgrades its standards to the level in force in the North, namely τ, and at the same time enjoys free trade as a reward with green tariffs *t* abolished.

The profit functions of the two firms are now

$$\pi_i^H = q_{ii}(p_i - c - \tau e_i) + q_{ik}(p_k - c - \tau e_i) - x_i \quad (4d)$$

[13] See appendix I for the derivations.

for i=N, S and k≠i, where superscript H stands for harmonized environmental standards. In this case, quantity produced by each firm for the domestic and the foreign market is identical:

$$q_{ii}{}^{H} = q_{ik}{}^{H} = \frac{1-\tau e_i}{3} \tag{6d}$$

for i=N, S and k≠i. The optimal amount of R&D expenditure by each firm is:

$$x^{H} = \left[\frac{2\tau(1-\tau e_0)}{9-2\tau^2}\right]^2 . \tag{7d}$$

For R&D to be positive in the case of harmonized standards it is necessary that $\tau < \frac{1}{e_0}$. Note that pollution abatement R&D by the Southern firm is now positive due to standards being enforced in the South, indicating a R&D creating effect.

The profits of the two firms are symmetric under harmonized standards and are

$$\pi_i^{H} = \frac{2(1-\tau e_0)^2}{9-2\tau^2} \tag{8d}$$

for i=N,S. Profits are lower for both firms the more stringent is the emission tax. As the multinational is indifferent about location with liberalized trade and symmetry in environmental policy, it is assumed that each firm remains in its home country. When standards are asymmetric on the other hand, the Northern firm decides whether to export, undertake FDI or delocate as explained in section 2.3, depending on the values of t and τ.

Figure 2 compares pollution abatement R&D effort under green tariffs with that after environmental harmonization/trade liberalization for different combinations of t and τ. Environmental harmonization creates positive abatement R&D in the South. Yet, the Northern firm no longer enjoys the cost advantage provided by green tariffs. This lowers production by the Northern firm for its domestic market except for high values of τ. This is because a high τ now translates into a higher tax for both firms and no longer brings a unilateral cost advantage for the Southern firm. R&D effort and expenditure is hence ‘shared’ among firms. The exporting case brings maximum effort of pollution abatement for a large region in the figure. While an industry with a base emission of e_0=1 is illustrated, this area expands (shrinks) for less (more) pollution intensive industries. FDI triggers a higher level of R&D expenditure when green tariffs and pollution taxes are both high.[14]

Bearing in mind the appropriate locational outcome for different combinations of t and τ under asymmetric standards (figure 1), R&D effort by the Northern multinational is always higher than harmonization as long as at least part of its production takes place at home (i.e. no delocation where ${x_N}^D = 0$). Environmental harmonization therefore only leads to a higher R&D effort when the standards required are stringent, especially when green tariffs upon non-compliance are relatively low. This area overlaps with the region where the lack of harmonization results in delocation and zero R&D.[15] Yet, it must be considered that a higher tariff can deter delocation in this case and results in a higher R&D effort than harmonization.

At this point, it can be concluded that green tariffs shift production to the North, where environmental standards are respected, by either discouraging dirty imports or deterring delocation. Since technology is not fixed, the Northern firm's strategic behavior in the former case brings a higher level of abatement R&D. R&D is induced by the higher market share granted to the Northern firm by green tariffs. An extreme case is prohibitive tariffs ($q_{SN}=0$), which gives the Northern firm a monopoly position in its home market. Here, Northern R&D is always higher with green tariffs than with environmental harmonization (see figure 2). With harmonization, standards are respected everywhere, but R&D by the Northern firm is often lower as the market and hence R&D expenditure is shared. In fact, environmental harmonization only brings a higher effort of pollution abatement when delocation (no R&D) is the outcome in its absence. Even in those situations a higher green tariff deters delocation and results in a higher R&D effort than harmonization.

Result 4

While a green tariff generate a cost advantage for and induce R&D by the Northern firm, environmental harmonization creates abatement R&D in the South by dividing the market and

[14] See appendix II for the derivations.

[15] This is because ($t^{x^F = x^H} < \bar{t}$ and $\tau^{x^E = x^H} > \tau^{\pi^E = \pi^D}$). See appendix I and II for proof.

R&D expenditure between firms. A green tariff results in a higher R&D effort by the Northern firm unless delocation is the outcome in its absence. A higher tariff in this case can however deter delocation and result in higher R&D.

4. The Environment

We can now use the results obtained on production, pollution abatement R&D, and the location decision of firms to evaluate and compare the effect of punishing green tariffs on the environment with that of an integrated economy with harmonized environmental standards. Pollution in this model is assumed to be of the transboundary type; thus, we examine total world pollution.[16]

Total pollution varies depending on where the Northern multinational chooses to locate production. Starting with the case of no standards, when the multinational exports or has a local plant in each country total emissions are respectively

$$E^E = (e_0 - \sqrt{x_N^E})[q_{NN}^E + q_{NS}^E] + e_0[q_{SN}^E + q_{SS}^E], \tag{10a}$$

$$E^F = (e_0 - \sqrt{x_N^F})[q_{NN}^F + q_{NS}^F] + e_0[q_{SN}^F + q_{SS}^F], \tag{10b}$$

where E represents total world emissions released from production. Note under FDI that because knowledge has a public good character and can easily be transferred across borders, the Northern firm can also use its enhanced technology in the facilities it runs in the South.

To see the effect of environmental policies on the environment, first recall that green tariffs increase total 'clean' production in the North and reduce total 'dirty' production in the South ($\frac{\partial q_{NN}^E}{\partial t} > 0, \frac{\partial q_{NS}^E}{\partial t} > 0, \frac{\partial q_{NN}^F}{\partial t} > 0, \frac{\partial q_{SN}^E}{\partial t} < 0, \frac{\partial q_{SS}^E}{\partial t} < 0, \frac{\partial q_{SN}^F}{\partial t} < 0$), while a unilateral Northern pollution tax does the opposite ($\frac{\partial q_{NN}^E}{\partial \tau} < 0, \frac{\partial q_{NS}^E}{\partial \tau} < 0, \frac{\partial q_{NN}^F}{\partial \tau} < 0, \frac{\partial q_{SN}^E}{\partial \tau} > 0, \frac{\partial q_{SS}^E}{\partial \tau} > 0, \frac{\partial q_{SN}^F}{\partial \tau} > 0$).

Green tariffs also always increase pollution abatement R&D ($\frac{\partial x_N^E}{\partial t} > 0, \frac{\partial x_N^F}{\partial t} > 0$), hence reducing unit emissions from the increased 'clean' production in the North by greening the

[16] Note that most MEAs deal with transboundary or global issues. If pollution is local, there is no role for a MEA or the WTO.

technology even further. On the other hand, a higher τ only initially increases abatement R&D for a lower scale of production in the North, while leaving the technology of increased 'dirty' production in the South unchanged.

If the multinational completely delocates, total emission in the South and the world becomes

$$E^{D} = e_0 (q^{D}_{NN} + q^{D}_{NS} + q^{D}_{SN} + q^{D}_{SS}) , \qquad (10c)$$

as all production takes place in the South and neither firm has an incentive to engage in R&D. Pollution tax does not play a role on the environment when delocation is the outcome, while green tariffs reduces pollutions by reducing production in the South ($\frac{\partial q^{D}_{NN}}{\partial t} < 0, \frac{\partial q^{D}_{SN}}{\partial t} < 0$).

Under harmonized standards, each firm remains in its home country and emissions in both regions are identical giving a total level of world pollution

$$E^{H} = (e_0 - \sqrt{x^{H}})(q^{H}_{NN} + q^{H}_{NS} + q^{H}_{SN} + q^{H}_{SS}) . \qquad (10d)$$

With environmental harmonization and trade liberalization, a global pollution tax increases pollution abatement R&D up to a threshold τ, while lowering production everywhere.[17]

Comparing (10a), (10b) and (10c) with (10d) reveals that for a low enough τ, green tariffs could result in a cleaner environment because the strategic behavior of the Northern firm highly affects the amount it invests in green R&D. Green tariffs are more effective because they shift production from the South to the clean North, where the enforcement of standards induces even further abatement. On the contrary, under environmental harmonization τ simply reduces production by all firms. Environmental harmonization however does have a positive effect on the environment by creating abatement efforts in the South. In sum, when the R&D inducing effect of green tariffs dominates the R&D creating effect of environmental harmonization, the former results in a cleaner environment. The higher the green tariff, the

[17] The reader must bear in mind that high values of τ do not make much practical sense in the environmental harmonization case as they only reduce production by all firms symmetrically.

larger is the range of τ over which green tariffs are more effective. This range is also larger when the Northern firm exports than when it engages in FDI.[18]

Result 5

Green tariffs could benefit the environment more than a policy of environmental harmonization by (1) shifting production to the region, where environmental standards are respected, (2) strategically inducing abatement R&D by the Northern firm by granting the latter a higher market share, (3) deterring delocation to the South. When these outweigh the R&D creating effect of environmental harmonization in the South, green tariffs are preferred.

Pollution could also be lower with green tariffs because the latter increases the market power of the Northern firm in its domestic market. If all goods are produced by a Northern monopolist under prohibitive green tariffs rather than two symmetric firms under harmonized standards, the green R&D effort by the former is higher than that by each of the latter firms (see figure 2). Unit emission is therefore lower on all production. In addition, total production is reduced as the Northern firm moves closer towards a monopoly position. On the other hand, harmonization results in symmetric Cournot and with it lower R&D effort, higher competition, higher total production, and more pollution.

Result 6

The strategic R&D-inducing effect of a green tariff is stronger the closer it brings the Northern firm to a monopoly position in its home market. Unit emissions and total world pollution could hence be lower when all production is done by a Northern monopolist that engages in more R&D than two symmetric firms under harmonization. Total emission is also less in this case due to less competition, hence a lower scale of world production.

Figure 3 illustrates the regime that brings more environmental benefits for different combinations of t and τ. Two pollution intensity levels of $e_0=1$ and $e_0=1/2$ are shown. It can be seen in the figure that when the industry is less pollution intensive, both $E^E = E^H$ and

[18] Equations of the two dividing have been omitted from the text as they involve tedious calculations. Derivations are available from the author upon request.

$E^F = E^H$ curves shift down. From an environmental perspective, this makes green tariffs a more attractive policy than harmonization for a larger range of τ. This is because when e_0 is lower, green tariffs result in higher abatement efforts than harmonization for a larger range of τ. A lower e_0 also makes the move towards monopoly, made possible through *t*, easier for the Northern firm. A higher e_0 simply puts higher restrictions on upper bound values of *t* and τ.

The results suggest that the required standards and pollution intensity must be high for harmonization to have any positive implication for the environment. Specifically, when green tariffs are allowed upon non-enforcement of environmental standards in the South, total world pollution is lower than when standards are harmonized and trade liberalized, up to a threshold value of τ. Green tariffs can hence be deemed a more effective tool to reduce world pollution when the emission tax in the North is at a modest level. Higher green tariffs expand the range of τ for which this is true.[19]

As a final note, we use the results obtained above to see how a green tariff policy affects other components of global welfare in comparison with environmental harmonization. Namely, we look at the impact of the two policies on consumers as a whole and each of the two producers. Total world consumer surplus is the area under the demand curve and can be written as half of the total output squared:

$$CS_i^{\ j} = \frac{(q_{NN}^j + q_{NS}^j + q_{SN}^j + q_{SS}^j)^2}{2} \tag{11}$$

for *j= E, F, D, H*. Because a green tariff lowers competition and a smaller scale of total world production, it generates a lower consumer surplus as long as τ is not too high to make the harmonization of environmental standards result in lower production. A higher *t* increases the

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[19] Although all levels of pollution tax are demonstrated here, many studies such as Noerdstrom and Vaughan (1999) show that pollution related costs only constitute a very small proportion of a firm's total costs. These costs only come up to no more than 1% of production costs for an average industry in the North and at most 5% for the most pollution intensive industries. We therefore emphasize the results for low enough levels of emission tax.

range of τ, where environmental harmonization brings a higher consumer surplus. Notice that this stands in conflict with environmental interests because the area, which results in a cleaner environment causes a lower consumer surplus.

Next, producer surplus, which is the operating profits for each firm, can be simplified to

$$\pi_i^j = {q_{iN}^j}^2 + {q_{iS}^j}^2 - x_i^j \qquad (12)$$

for j= E, F, D, H and i= N,S. Because tariffs reduce production by the Southern firm, the latter is also harmed by a green tariff unless τ is so high that environmental harmonization results in less output. The same argument under consumer surplus holds for the Southern firm. On the other hand, the analysis showed that the Northern firm benefits from green tariffs by gaining a higher market share and market power. A larger scale of production by the Northern firm makes the area that brings a cleaner environment coincide with that in which the Northern firm prefers a green tariff policy (high t, low τ). Only in the case of delocation per se the opposite is true as green tariffs simply reduce production by the Northern firm as they do the profits of the Southern firms.

This observation shows that the disutility from pollution must be measured against utility from the other components of welfare to find the optimal environmental policy. Green tariffs are also welfare optimal if the global concern about the environment is significant enough to outweigh the disutility caused by tariffs to world consumers and firms that would otherwise operate in regions with no environmental restrictions. If the opposite holds, harmonization of standards along with trade liberalization is the socially optimal policy choice.

5. Conclusion

This paper emphasizes the importance of trade obligations in MEAs to improve the quality of the environment in a global level. It introduces and analyzes the roles of green tariffs in a framework, which encompasses the decision on firms on pollution abatement R&D and production location. It shows that trade policy measures should be considered to reach environmental targets as they have clear ‘green’ consequences by affecting the decision of firms on R&D and location. Green tariffs are shown to indeed serve the purpose of environmentalists: green tariffs not only shift production to a region where environmental standards are enforced, but also strategically induce the innovation of even greener technologies by giving firms there a higher market power. The latter serves in the best interest of the environment by creating lower unit emissions from production and a lower scale of world production than environmental harmonization.

The paper seeks the optimal combination of policies for the environment in the light of Carraro and Siniscalco (1994) and finds that green tariffs with no environmental restrictions in the South may result in a cleaner environment than a mixed policy of harmonization and trade liberalization.[20] Tariffs are hence green in the sense that there exists a level of taxation of imports from environmentally lax countries that result in lower global pollution levels than forcing them to impose a per-unit emission tax equal to that enforced in strict countries.[21]

The framework serves as a good starting point by demonstrating the basic roles of green tariffs in constituting the environment by concentrating on pollution abatement R&D and the location of production. An important extension to the model would be to look at more direct measures of improving the environment such as R&D subsidies to avoid creating a distortion. The paper also leaves room for more work on games between governments regarding endogenous policies on trade and environment. Endogenous tariffs by governments in the North or the WTO that aim for a cleaner environment can for instance manipulate the South to harmonize its standards when the latter is welfare improving. It would also be interesting to find the optimal green tariff for different levels of pollution tax taking into consideration its impact on Southern policies. It can then be assessed whether green tariffs are more useful as a direct tool or as a credible threat for a successful move towards a better environment.

[20] Cararro and Siniscalco (1994) also argued that environmental targets can be better reached through a mix of complimentary policy measures rather than conventional environmental restrictions.

[21] An example of unsatisfactory achievements of conventional environmental regulations is the evidence presented by the European Commission in case of the European carbon tax that showed that a 'very high' carbon tax achieves only about one half of the required reduction target. (Carraro and Siniscalco, 1994)

Appendix I: Location of the Multinational

The decision of the multinational on where to locate production is based on the profits it makes under each scenario. The threshold fixed cost of relocation $\overline{\Gamma}$ was derived in the main text to find out the dividing line between exporting and FDI. Looking at figure 2 shows that this decision depends very little on *t* and that exporting occurs for lower values of τ. This is because the only other difference between exporting and FDI is that the latter implies savings on pollution tax for production aimed at the Southern market. Similarly, threshold $\bar{t}$ determined the dividing tariff rate between FDI and delocation. The decision between exporting and delocation is derived in the same manner by finding the emission tax ceiling, under which exporting is chosen ($\pi^E = \pi^D$):

$$\tau^{\pi^E = \pi^D} = \frac{3\left(3e_0(2-t) + \sqrt{[(2-t)^2 - 18\Gamma][9(e_0{}^2 - \Gamma) - 4t]}\right)}{2[(2-t)^2 + 18(e_0{}^2 - \Gamma)]} . \tag{A.1}$$

The locational decision of the Northern firm is illustrated using $\overline{\Gamma}$, $\bar{t}$ and (A.1) as in figure 1.

Appendix II: Pollution Abatement R&D

The critical levels of tariffs and pollution tax that make pollution abatement R&D equal under different scenarios are derived as follows. First, there is a threshold pollution tax under which the multinational engages in more R&D under the exporting scenario than when it engages in FDI. This level of R&D solves for the τ that makes (7a) and (7b) equal, namely

$$\tau^{x^E=x^F} = \frac{3(3e_0 - \sqrt{9e_0{}^2 - 4t})}{4t}. \qquad \text{(A.2)}$$

When environmental harmonization comes into play, then (7d) must be compared with R&D under each of the two scenarios with asymmetric standards, i.e. (7a) and (7b). First solving for the ceiling tax rate under which exporting results in a higher R&D effort than harmonization we get

$$\tau^{x^E=x^H} = \frac{3(9e_0 - \sqrt{81e_0{}^2 + 8[t^2 - t - 2]})}{4(2-t)}. \qquad \text{(A.3)}$$

Notice that the threshold tariff rate that makes R&D effort under exporting and harmonization equal can be obtained in a similar manner. Alternatively, the minimum tariff rate required for FDI to yield higher R&D investment than with harmonization is:

$$t^{x^F=x^H} = \frac{\tau(9e_0 - 2\tau)}{9 - 2\tau^2}. \qquad \text{(A.4)}$$

Using the combination of (A.2), (A.3) and (A.4) we can find the scenario, which brings the highest pollution abatement effort in different circumstances as depicted in figure 1.

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Figure 1: Location Decision of the Multinational

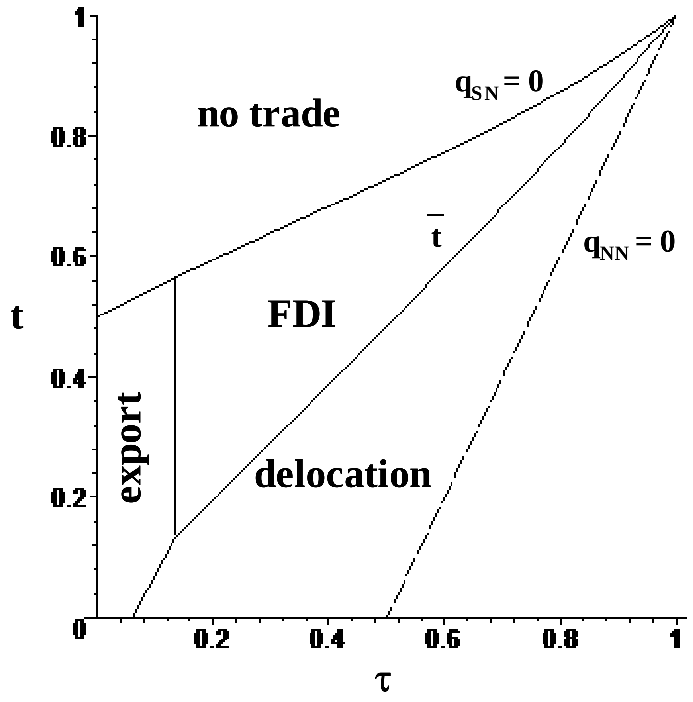


Figure 2: Maximum Pollution Abatement R&D

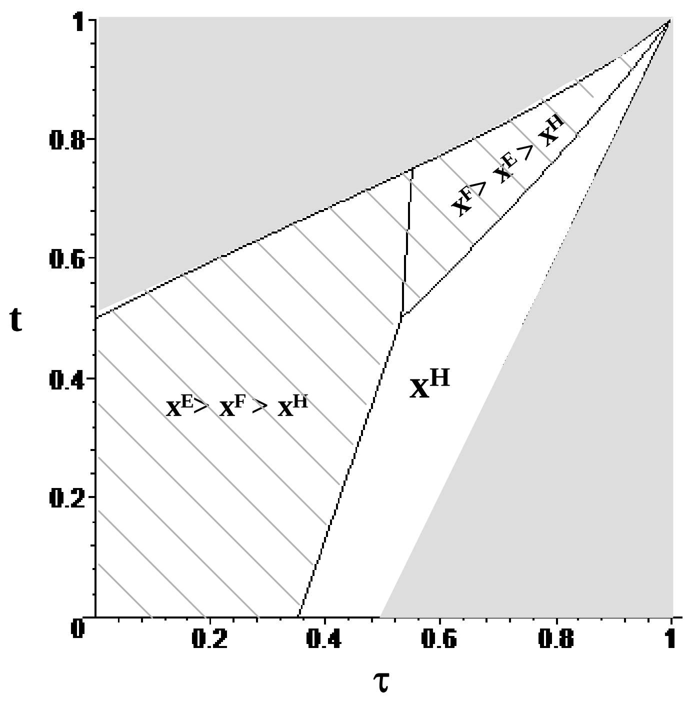
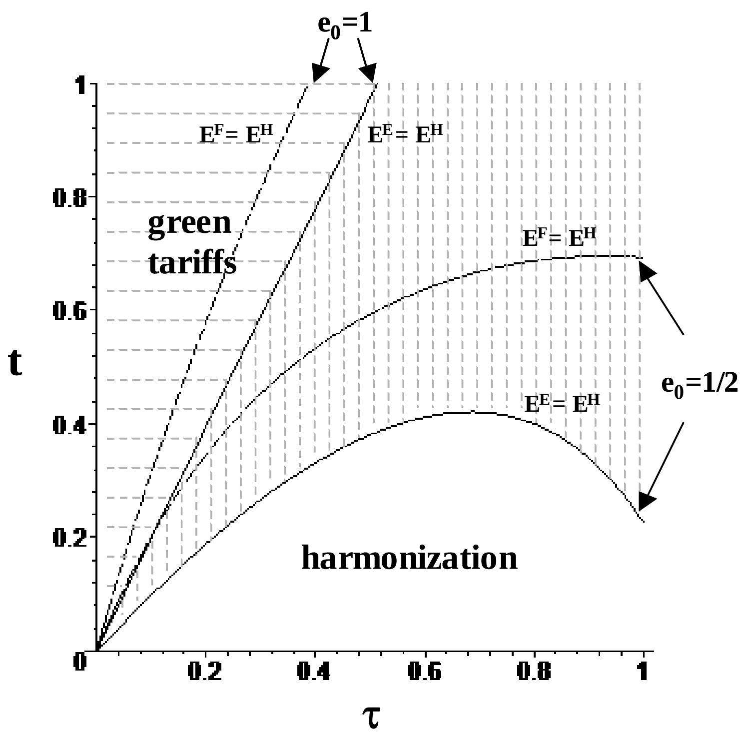


Figure 3: Effective Environmental Policy



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