Environmental Taxation and Trade Liberalization in Environmental Goods and Services

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Abstract

This paper seeks to formally analyze the debate that has surrounded the Doha Declaration paragraph that urges both developed and developing countries to be committed to negotiating "the reduction or, as appropriate, elimination of tariff and non-tariff barriers to environmental goods and services". We develop a simple two country model in which an international monopolistic eco-industry interacts with local perfectly competitive polluting industries. In non-producing countries of environmental goods and services, we show that one cannot make an unequivocal connection between trade liberalization in these goods and services and more environmental performance. Indeed, for an importing country of environmental goods and services, if its purchased quantity of such goods and services increases with the stringency of environmental regulation, an exogenous reduction in its import tariffs on these goods and services gives rise to a less stringent environmental taxation. Our results also suggest that this clear interplay between trade and environmental policies does not simultaneously ensure price decrease and demand increase on the environmental market of the importing country.

Keywords: eco-industry, environmental taxation, trade liberalization

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1. Introduction

With the view to enhancing the mutual supportiveness of trade and environment, the World Trade Organization (WTO) has recognized, at its fourth Ministerial meeting held in Doha (Qatar) in 2001, the importance of liberalizing trade in environmental goods and services. A significant step forward in the Doha Development Agenda is the WTO commitment to negotiating, without prejudging the outcome, "the reduction or, as appropriate, elimination of tariff and non-tariff barriers to environmental goods and services[2]" (WTO, 2001).[3]

The WTO has been claiming that trade liberalization in environmental goods and services (EGS) would benefit both developed and developing countries by enhancing environmental protection and promoting economic development. On one hand, polluting firms in developing countries, which mainly import EGS, will likely increase their abatement demand as a result of reduced prices stemming from import tariff cuts. In turn, this decrease in compliance costs would likely induce local governments to put in place more ambitious environmental targets. On the other hand, developed countries, which export EGS, would benefit from new market opportunities as a result of tariff reductions. This would translate in more economic development by generating more revenues and employment in those countries where eco-industrial activities are located. At the regional and

[2]Environmental goods and services consist of goods and services that are used to measure, prevent, limit, minimize, or correct environmental damage to water, air, and soil, as well as problems related to waste, noise and eco-systems. They include cleaner technologies, products and services that reduce environmental risk and minimize pollution and resource use (OECD and Eurostat, 1999).

[3]Paragraph 31(iii) of the Doha Ministerial Declaration.

international levels, increasing trade in EGS would furthermore translate in significant technology and knowledge transfer towards importing countries.

A number of regional trade agreements have also specifically addressed EGS liberalization. During the late 1990s, for example, the Asia-Pacific Economic Cooperation (APEC) economies identified EGS as priority sectors for early voluntary liberalization. They were intending to have zero-tariffs by 2005 or before in almost all member countries. The US-Jordan Free Trade Agreement, which entered into force in December 2001, constitutes another example. It was aiming to eliminate over ten years tariffs on many environmental goods and to remove trade restrictions on certain environmental services. Also, the Canada-Costa Rica Free Trade Agreement, which entered into force in October 2002, provided immediate duty-free access to most environmental goods.

Yet, much of the story about the potential benefits of trade liberalization in EGS lacks consensus. For example, since the applied and bound tariffs on EGS are lower in developed countries than in emerging and least-developed countries, most of the latter countries believe that liberalization of trade in EGS might benefit more developed countries. Clearly, trade liberalization in EGS is still not worldwide perceived in the same way. A note by Hamwey et al. (2003) on liberalization of international trade in environmental goods and services illustrates well this disagreement. This note states that "direct trade gains from liberalization in environmental goods and services may flow largely to the most advanced WTO members, which stand to benefit from improved access to expanding environmental goods and services markets in developing countries."

Another recurrent theme while addressing issues regarding liberalizing trade in EGS, especially those in relation to the operation of infrastructure facilities, corresponds to the reluctance on the part of developing countries to make commitments with multinational eco-industrial firms related to the provision of environmental services such as sewage collection and treatment, and solid waste-management for fear that poorer members of their populations might have difficulty accessing these services. Seemingly, countries do not feel safe when their essential public infrastructure are internationally owned and controlled.

To understand the source of this lack of common ground, it suffices to notice that firms owned by OECD member countries currently account for about 90% of the commercial market for EGS.[4] Furthermore, over-capacity of EGS produced in OECD countries has slowed market growth in many of their domestic markets and the most rapid rates of growth now occur in transition and developing countries (Kennett and Steenblik, 2005). Therefore, similar to the reason following which some countries have chosen to specialize in the production of wheat, coffee, or clothing, OECD member countries are now specializing in the production of EGS.

In this context of international trade in EGS, import tariffs on EGS can play at least two roles in non-producing or non-efficiently producing countries of such goods and services. First, following the literature on foreign domestic investments (FDI) inducement

[4] In 1998, the Brazilian state-owned company, SABESP, was the only company from a developing country ranked among the world's top 50 environmental companies (WTO, 1998). Furthermore, nowadays, of the top ten largest companies providing EGS, four are from the USA, two each from France and Japan, and one each from Germany and the UK (Simpson, 2006).

(Corden, 1974; Svedberg, 1979), they can lead to technology transfer through FDI or joint ventures targeting eco-industrial activities. Second, even in the absence of FDI, if exporters of EGS enjoy a non-competitive environment, import tariffs can be welfare improving as they permit importing countries of EGS to extract rents from international eco-industrial firms.[5]

The impact of the reduction of import tariffs on polluting goods, and more generally trade liberalization in polluting goods, on the quality of the environment has been extensively studied in the economic literature on trade and environment.[6] Nonetheless, to the best of our knowledge, there have not yet been any formal analyses of the effects of trade liberalization in EGS. Recent papers by Feess and Muehlheusser (1999, 2002), Copeland (2005), Canton (2007), as well as Greaker and Rosendahl (2006) study the impact of international trade in EGS on the design of environmental policy. However, they do not address any issues related to trade liberalization in such goods and services. Therefore, the distinguishing feature of our paper is that we incorporate some aspects of trade liberalization in EGS. Moreover, unlike these previous studies that analyze the impact of international trade in EGS on optimal environmental regulation, we extend our analysis to study the impact of trade liberalization in EGS on the total level of emissions in the environment.

To analyze the impact of trade liberalization in EGS on the quality of the environment,

[5]For more details about the intuition behind tariff induced welfare improvement in the absence of FDI, see Brander and Spencer (1981), Katrak (1977), Tanaka (1992), Hillman and Templeman (1985).

[6]For an overview of the linkage between environmental policy and trade policy related to polluting goods, see Barrett (1994), Conrad (1993), Copeland (2000), Hamilton and Requate (2004), Kennedy (1994), Long and Soubeyran (2000), and Walz and Wellisch (1997).

we study how an exogenous reduction in import tariffs on EGS would affect, at the margin, the structure of environmental taxation in an importing country of EGS, as well as its purchased quantity of these goods and services. For this purpose, we develop a simple two country model of international trade in EGS, in which an international monopolistic eco-industry offers its goods and services to perfectly competitive local polluting industries.

In our model, import tariffs on EGS play the role of rent extraction from the monopolistic eco-industry. In other words, to keep simple our analysis, we ignore the potential role of import tariffs to induce FDI in eco-industrial activities.[7] We seek to answer the following two questions. Suppose an international accord stating that import tariffs on goods and services that deal with a specific pollutant must be cut by a given amount, how would the government regulator in an importing country of these EGS adjust environmental taxes imposed on this pollutant? How would these changes in trade and environmental policies affect prices and exchanged quantities on the environmental market of the importing country, as well as the quality of its environment?

Our analysis shows that one cannot assert that trade liberalization in EGS would, as put forward by the WTO and the OECD, unambiguously promote environment protection throughout the world. Indeed, in the importing country of EGS, if the purchased quantity of EGS increases with the stringency of environmental regulation, trade liberalization gives rise to a less stringent environmental taxation. Our results also suggest that this clear

[7] The inclusion of the FDI inducement role of import tariffs on EGS would have required considerations about intellectual property protection, which is one of the most important determinants of FDI. This is left for future research.

interplay between trade and environmental policies does not simultaneously ensure price decrease and demand increase on the market of EGS.

The remainder of the paper is structured as follows. Section 2 develops our model of international trade in EGS, which studies the interplay between trade and environmental policies. Next, section 3 endogenizes conditions for the setting of environmental taxes in both the exporting and importing countries of EGS. Then, section 4 analyzes the effects of an exogenous import tariff reduction on environmental taxes, on the amount of purchased EGS and on their prices. Finally, concluding comments and suggestions for future research are provided in section 5.

2. The model

Let us frame our model around two countries: a domestic (or home) country, denoted hereafter by the subscript h, and a foreign country, which we denote by the subscript f. Suppose that eco-industrial activities are technologically or financially unviable in the foreign country; and consider an international monopolistic eco-industry that is owned and located in the domestic country.

This eco-industry produces a homogeneous environmental good or service that is sold in both the domestic and foreign countries. The domestic eco-industry has a cost function denoted by $G(A_h)$, where A_h represents the total output of this eco-industry.[8] The cost

[8] To easily compare our results with those derived in the same strand of literature in environmental economics (David and Sinclair-Desgagné, 2005; David, Nimubona and Sinclair-Desgagné, 2006; Canton, 2006; Canton, Soubeyran and Stahn, 2005; and Nimubona and Sinclair-Desgagné, 2005), we follow as closely as possible their framework as well as their notation.

of producing EGS is assumed to increase in production ($G'(A_h) > 0$) and to be linear ($G''(A_h) = 0$).

The eco-industrial firm sells a_h in the home country and a_f in the foreign country. We assume that the domestic and foreign markets of EGS are segmented.[9] These markets are composed of polluting firms that purchase EGS to mitigate the pollution damage associated with their process of production. In each country, these polluting firms produce a homogenous consumption good within a local perfectly competitive market. In other words, polluting firms do not compete in the international market. Throughout, we also assume the pollution damage to be local.

In the same way as previous papers dealing with environmental outsourcing (David and Sinclair-Desgagné, 2005; David, Nimubona, and Sinclair-Desgagné, 2006; Canton, 2007; Canton, Soubeyran, and Stahn, 2005; Nimubona and Sinclair-Desgagné, 2005), we consider that polluting firms proceed with an end-of-pipe pollution abatement. The representative polluting firm's emission level in country i - with $i = h, f$ - is therefore given by the following additively separable function: $e_i(x_i, a_i) = w(x_i) - \epsilon(a_i)$, where a_i is the total demand for EGS and x_i is the total output of the polluting industry in country i. We assume this emission function to be twice continuously differentiable: $w'(x_i) > 0$ (production generates pollution), $w''(x_i) \geqslant 0$ (increasing marginal pollution), $\epsilon'(a_i) > 0$ (abatement effort reduces pollution), and $\epsilon''(a_i) < 0$ (decreasing returns to abatement). Like David and Sinclair-Desgagné (2005), we also suppose that $\epsilon'(a_i) + a_i\epsilon''(a_i) > 0$. This

[9] Furthermore, the linear function of production costs of EGS allows us to separate the eco-industry's decisions in the two environmental markets.

latter relation implies that the emission function is not too convex in abatement efforts. It constitutes a sufficient condition for the equilibrium purchased quantities of EGS to increase with the stringency of environmental regulation.

National policy makers in both the domestic and foreign countries have access to two policy instruments - an emission tax and an import tariff on EGS - both of which affect the market of EGS. On one hand, a national regulator in country i introduces an environmental tax t_i to tackle the local pollution problem. In the presence of such an environmental policy, the environmental market is characterized by an inverse demand function $q_i(a_i, t_i)$, where q_i and a_i stand for the price and total demand for EGS in country i. On another hand, following Katrak (1977), Brander and Spencer (1981), Dixit (1984), and Tanaka (1992), we suggest that an importing country of EGS has an incentive to extract rents from the monopolistic eco-industry by imposing a trade tariff on its imports of EGS. Therefore, the foreign country imposes a specific tariff τ on its imports of EGS. We assume that this trade barrier is exogenously determined with respect to environmental regulation. In contrast, the latter can be adjusted in response to any changes in the level of the import tariff.

To keep simple our analysis, we ignore the FDI inducement by tariff barriers. Undoubtedly, eco-industrial firms create subsidiaries in host countries for most of their contracts abroad (Steenblik, Drouet and Stubbs, 2005). This seems to result, at least partly, from the presence of tariff and non-tariff barriers to trade in EGS. To be consistent with this stylized fact, we assume that the subsidiary's profits in the foreign country are totally attributed to its parent body located in the domestic country.[10]

We are ultimately interested in how an exogenous reduction of these import tariffs on EGS would affect the quality of the environment in the foreign country. This impact of trade liberalization in EGS on environmental performance can be interpreted as the outcome of a four-stage game. In the first stage, governments of the domestic and foreign countries negotiate on the reduction of import tariffs on EGS. In the second stage, the national regulator in each country sets an optimal environmental tax, taking as given the outcome of trade negotiations as well as the level of the environmental tax in the other country. In the third stage, the eco-industrial firm determines the quantities of EGS that it will supply to polluting industries located in both countries. In the last stage, these polluting firms express their demand for EGS while competing locally to supply the final good.

3. Environmental taxation

This section analyzes the process of environmental taxation in both the domestic and foreign countries. The following subsections analyze each of the three last stages of our game which follow trade negotiations. While analyzing the setting of environmental taxes in the foreign country, we specifically point out the interplay between trade and environmental policies. As usual, we solve our model backward beginning with the behavior of

[10]Note that if the eco-industrial firm located in the domestic country had a subsidiary in the foreign country and attributed its profits on the foreign market to this subsidiary, the foreign country would better use a tax on profits to extract rents from the domestic eco-industry.

polluting industries.

3.1. The demand for environmental goods and services

Let $C(x_i)$ be the production cost function of a representative polluting firm in country i. This cost function is assumed twice differentiable, strictly increasing ($C'(x_i) > 0$) and convex ($C''(x_i) > 0$). In the presence of an environmental tax, a representative polluting firm in country i chooses its level of demand for EGS while maximizing its profits. These profits are given by the following function:

$$\Pi_i(x_i, a_i) = P_i x_i - C(x_i) - q_i a_i - t_i [w(x_i) - \epsilon(a_i)],$$

where P_i is the current price of the consumption good. To maximize its profits function, the representative polluter sets its marginal revenue equal to its marginal cost of production, and its marginal cost of pollution abatement equal to the marginal benefit of pollution abatement, i.e.

$$P_i = C'(x_i) + t_i w'(x_i), \quad (1)$$

$$q_i = t_i \epsilon'(a_i). \quad (2)$$

Expression (2) yields the optimal inverse demand function for EGS in country i, i.e. $q_i(a_i, t_i) = t_i \epsilon'(a_i)$. This inverse demand function is downward sloping ($\frac{dq_i}{da_i} = t_i \epsilon''(a_i) < 0$). Moreover, as pointed out in Requate (2005a) and David *et al.* (2006), any change in the level of the emission tax t_i has two distinct effects on the pollution abatement demand curve: a level effect ($\left.\frac{dq_i}{dt_i}\right|_{a_i} = \epsilon'(a_i) > 0$) and a rotation effect ($\frac{\partial^2 q_i}{\partial a_i \partial t_i} = \epsilon''(a_i) < 0$). The level effect means that the willingness for polluters to buy EGS increases with the stringency of environmental taxation. This translates graphically in an upward shift of the inverse demand curve for EGS. In turn, the rotation effect means that the price-sensitivity of the pollution abatement demand decreases with the stringency of environmental taxation. Diagrammatically, this corresponds to a clockwise rotation of the inverse pollution abatement demand curve. These characteristics of the demand of EGS are important in the following analysis of the supply side of the market for EGS as well as the determination of optimal emission taxes.

3.2. The supply of environmental goods and services

To determine its optimal supply of EGS, the eco-industry solves the following program:

$$\underset{a_h, a_f}{Max} \qquad \Pi_h = q_h(a_h, t_h) a_h + [q_f(a_f, t_f) - \tau] a_f - G(A_h).$$

Recalling that A_h is the total output of the monopolistic domestic eco-industry and a_i represents the supply of EGS to country i, note that $A_h = a_h + a_f$. At the equilibrium, the behavior of the eco-industry is thus characterized by the following set of two equations:

$$\frac{\partial \Pi_h}{\partial a_h} = q_h(a_h, t_h) + q_h'(a_h, t_h) a_h - G'(A_h) = 0, \qquad (3)$$

$$\frac{\partial \Pi_h}{\partial a_f} = q_f(a_f, t_f) + q_f'(a_f, t_f) a_f - \tau - G'(A_h) = 0. \qquad (4)$$

These two relations, which correspond to the first-order conditions for profit maximization, yield the following solutions for our monopolistic eco-industry: $a_h^* = a_h(t_h)$ and $a_f^* = a_f(t_f, \tau)$. These solutions correspond to the equilibrium quantities of EGS supplied by the domestic eco-industrial firm to the domestic and foreign market, respectively. They suggest that the national level of the environmental tax in each country affects the supply of EGS addressed to this country. However, only the supply addressed to the foreign country depends on the level of import tariff in this country.

We show below how benevolent regulators, who choose optimal levels of environmental taxation, account for this impact of environmental regulation on the behavior of polluting and eco-industrial firms.

3.3. Optimal environmental taxes

In each country, the regulator chooses the optimal environmental tax, which maximizes the local social welfare. This social welfare is defined as the sum of the local consumers' surplus of the final good, polluting industry's profits, government's tax revenues, and either eco-industry's profits or government's tariff revenues, as appropriate, less the social damage due to pollution.

Precisely, the regulators in the domestic and foreign countries respectively solve the following programs:

$$\underset{t_h}{Max} \qquad W_h = \int_0^{x_h} P_h(z)\,dz - C(x_h) + [q_f(a_f, t_f) - \tau]\,a_f - G(A_h)$$

$$- v\,[w(x_h) - \epsilon(a_h)]\,, \quad (5)$$

$$\underset{t_f}{Max} \qquad W_f = \int_0^{x_f} P_f(z)\,dz - C(x_f) + [\tau - q_f(a_f, t_f)]\,a_f - v\,[w(x_f) - \epsilon(a_f)]\,. \quad (6)$$

Solving (5) with respect to t_h and (6) with respect t_f (computational details are provided in appendix C) gives the following expressions of optimal taxes for the domestic and foreign countries, respectively:

$$t_h = v + \frac{q_h'(a_h, t_h)\,a_h \frac{da_h}{dt_h}}{w'(x_h)\frac{dx_h}{dt_h} - \epsilon'(a_h)\frac{da_h}{dt_h}}, \quad (7)$$

$$t_f = v + \frac{a_f \frac{dq_f}{dt_f} - \tau \frac{da_f}{dt_f}}{w'(x_f)\frac{dx_f}{dt_f} - \epsilon'(a_f)\frac{da_f}{dt_f}}. \quad (8)$$

The first term on the right hand side of both expressions (7) and (8) corresponds to the Pigovian rate, i.e. the marginal social damage of polluting emissions. The denominator of the second term on the right hand side of (7) and (8) is negative (from standard comparative statics in appendix A and B.1., as well as our assumptions). This denominator represents the marginal effect of the pollution tax on total emissions. In turn, the numerator of the second term on the right hand side of (7) is negative. Therefore, the second term of expression (7) is positive. This implies that the optimal level of taxation in the domestic country is higher than the Pigovian rate. In the same way as in David and Sinclair-Desgagné (2005), and Requate (2005a), the intuition for this result is that the regulator in the domestic country needs to give strong incentives to domestic polluters to abate pollution up to a sufficient level despite high prices of EGS induced by the monopolistic behavior of the eco-industry.

However, the numerator of the second term on the right hand side of (8) comprises two new components. The first component ($\frac{dq_f}{dt_f}$) represents the price-effect of the emission tax on the compliance expenses of foreign polluting industries. These compliance expenses also correspond to export revenues of the domestic eco-industry. For not sufficiently convex pollution abatement demand functions, including linear and concave demand functions, we have that $\frac{dq_f}{dt_f} > 0$ (see details in appendix B.2). Therefore, in the presence of a monopolistic eco-industry, environmental taxation may increase the gap between the price and the marginal production cost of EGS. Put another way, for the foreign country, a more stringent emission tax may increase the marginal rent paid to the domestic eco-industry, unless the latter happens to earn only normal profits. The interpretation of this first component, together with the negative denominator, tells us that the government regulator in the foreign country needs to account for the impact of the emission tax on this gap between the price and the marginal production cost of EGS, which has a negative effect on social welfare.

Clearly, when this gap increases with the emission tax, the foreign country pays a rent to the domestic eco-industry by tightening environmental taxation. In this context, the foreign country may have an incentive to use an import tariff on EGS to capture some of this rent.[11] This idea transpires through the second component of the numerator. Indeed, this second component shows that the optimal emission tax in the foreign country depends on the cross effect of the import tariff and the tax-sensitivity of the demand for EGS. From appendix B.1., we have that $\frac{da_f}{dt_f} > 0$, i.e. the import demand for EGS increases with the emission tax. Hence, the second new component in (8) is negative. Together with the negative denominator, it shows that, while setting the level of environmental taxation, the regulator in the foreign country needs to account for the possibility to extract rents from the domestic eco-industry through tariff revenue increase. In fact, for a positive import tariff, if the import demand for EGS increases with the emission tax, tariff revenues increase with the tax as well. This counters the previous negative effect of a tighter emission tax on the social welfare.

Thereby, the net effect of these two new components determines the sign of $(t_f - v)$ in the foreign country. Moreover, this net effect depends on the level of the import tariff on EGS, τ.[12] When τ is significantly high, then the tariff revenue effect of the emission tax is likely higher in absolute value than its compliance expense effect. This induces an optimal level of taxation higher than the Pigovian rate.[13] Conversely, when τ is significantly low, the reverse holds, i.e. the optimal level of taxation is lower than the Pigovian rate. Specifically, for $\tau = 0$, the second term on the right hand side of expression (8) equals

[11]Although a tariff on EGS is attractive from the point of view of the foreign country, the revenues that it generates are at least somewhat offset by a loss in the consumer surplus of polluting firms.

[12]This result already suggests that import tariff variations in the foreign country might affect its structure of environmental taxation, depending on how the latter affect the import demand for EGS.

[13]This outcome is also always true when a tighter emission tax induces a decrease in the equilibrium price of EGS.

$\frac{a_f \frac{dq_f}{dt_f}}{w'(x_f)\frac{dx_f}{dt_f} - \epsilon'(a_f)\frac{da_f}{dt_f}} < 0$. In this case, the optimal tax in the foreign country is lower than the Pigovian tax for $\frac{dq_f}{dt_f} > 0$, and higher than the Pigovian tax for $\frac{dq_f}{dt_f} < 0$. All these findings are summarized in the following proposition.

Proposition 1. *If a country i relies exclusively on environmental goods and services imported from a monopolistic eco-industry to abate pollution, the direction of the adjustment of its optimal environmental tax (t_i) to the Pigovian rate (v) depends on the effect of this tax on the import price of these environmental goods or services ($\frac{dq_i}{dt_i}$) and the level of the import tariff (τ_i) imposed on them. For $\tau_i = 0$, $t_i \lesseqgtr v$ if and only if $\frac{dq_i}{dt_i} \gtreqless 0$. When τ_i is positive, t_i may be higher than, equal to, or lower than the Pigovian rate according to the following rule:$t_i \gtreqless v \quad iff \quad \tau_i \frac{da_i}{dt_i} \gtreqless a_i \frac{dq_i}{dt_i}$.*

The intuition of this proposition is as follows. Environmental taxation in an importing country of EGS increases the ability of an international eco-industry to capture the profits of polluting firms in this country. Therefore, in the absence of sufficiently high import tariffs on EGS, the government regulator in this importing country needs to lower the emission tax level with the aim to minimize the extent of the eco-industry to capture its polluting firms' profits. Conversely, when the importing country has the possibility to extract this increase in eco-industry's rents through tariff revenues, the environmental regulator naturally adjusts upward its optimal emission tax. Hence, the rents that polluting firms pay to an international eco-industry, which increase with the stringency of environmental taxation, explain the rationale of import tariffs on EGS. The next section determines the effects of a reduction in theses import tariffs in our economy.

4. Trade liberalization in environmental goods and services

The expression (8) of the optimal environmental tax in the foreign country, which imports EGS, suggests that import tariff variations affect the optimal structure of environmental taxation in this country.[14] As the level of import tariffs affects other components that determine the optimal emission taxes, our analysis nevertheless needs to consider the reactions to tariff variations of all endogenous variables in our model. In this section, we specifically study the net impact of trade liberalization on the equilibrium price and purchased quantities of EGS in the foreign country. In the end, this helps us to assess the impact of trade liberalization in EGS on the quality of the environment in the foreign country.

Let us first examine how an exogenous reduction in the import tariff rate would affect emission taxes and exchanged quantities of environmental goods and services. Comparative static analysis (computations are provided in appendix D) from equations (4) and (8) yields

$$\frac{dt_f}{d\tau} = \frac{\left(2q_f' + a_f q_f''\right)\frac{da_f}{dt_f} - \left[\frac{\partial q_f}{\partial t_f} + a_f \frac{\partial q_f'}{\partial t_f} + \left(t_f - v\right)\epsilon''\left(a_f\right)\frac{da_f}{dt_f}\right]}{-\left(2q_f' + a_f q_f''\right)\left[w'\left(x_f\right)\frac{dx_f}{dt_f} - \epsilon'\left(a_f\right)\frac{da_f}{dt_f} + \left(t_f - v\right)w''\left(x_f\right)\left(\frac{dx_f}{dt_f}\right)^2\right] - \left(\frac{\partial q_f}{\partial t_f} + a_f\frac{\partial q_f'}{\partial t_f}\right)\left[\frac{\partial q_f}{\partial t_f} + a_f\frac{\partial q_f'}{\partial t_f} + \left(t_f - v\right)\epsilon''\left(a_f\right)\frac{da_f}{dt_f}\right]}, \tag{9}$$

$$\frac{da_f}{d\tau} = \frac{-\left[w'\left(x_f\right)\frac{dx_f}{dt_f} - \epsilon'\left(a_f\right)\frac{da_f}{dt_f}\right] - \left(t_f - v\right)w''\left(x_f\right)\left(\frac{dx_f}{dt_f}\right)^2}{-\left(2q_f' + a_f q_f''\right)\left[w'\left(x_f\right)\frac{dx_f}{dt_f} - \epsilon'\left(a_f\right)\frac{da_f}{dt_f} + \left(t_f - v\right)w''\left(x_f\right)\left(\frac{dx_f}{dt_f}\right)^2\right] - \left(\frac{\partial q_f}{\partial t_f} + a_f\frac{\partial q_f'}{\partial t_f}\right)\left[\frac{\partial q_f}{\partial t_f} + a_f\frac{\partial q_f'}{\partial t_f} + \left(t_f - v\right)\epsilon''\left(a_f\right)\frac{da_f}{dt_f}\right]}. \tag{10}$$

[14] Trade liberalization clearly does not affect the environmental tax structure in the domestic country (see expression (7)).

We cannot straightforwardly sign expressions (9) and (10). But interestingly, when $t_f < v$,[15] the denominator in both expressions is always negative. From our assumptions, the numerator in expression (9) is also negative. Therefore, $\frac{dt_f}{d\tau} > 0$. This result implies that the levels of emission taxes and import tariffs on EGS in the foreign country vary in the same direction. Clearly, and as we were expecting, if an importing country cannot extract the rents paid by its polluting firms to an international eco-industry, its environmental regulator will adjust downward emission taxes with respect to the marginal social damage of pollution ($t < v$). Moreover he will adjust these emission taxes in the same direction as import tariff variations. This constitutes our second proposition.

Proposition 2. *When a country fully relies on environmental goods and services imported from a monopolistic eco-industry, and if import tariffs on these goods and services cannot help to successfully extract rents from the eco-industry, then trade liberalization in environmental goods and services gives rise to a less stringent optimal environmental tax.*

The standard expectation of the proponents of trade liberalization in EGS is that the global demand for these goods and services would increase as trade barriers fall. But our finding that a decrease in the stringency of environmental taxation would result from trade liberalization in EGS also suggests that the total demand for EGS might decrease in the foreign country as a consequence of this lax environmental taxation. Nevertheless,

[15] Recall that $t_f < v$ implies that $\tau \frac{da_f}{dt_f} - a_f \frac{dq_f}{dt_f} < 0$. This says that the import tariff on EGS is not high enough to allow the foreign country to totally extract the marginal increase, which is induced by a tighter emission tax, in the rents paid by its polluting firms to the domestic eco-industry.

the sign of the numerator in expression (10) is always positive, which implies that $\frac{da_f}{d\tau} < 0$. This shows that, despite the decrease in the stringency of environmental taxation, imports of EGS in the foreign country increase when import tariffs on these goods and services decrease. Therefore, we can conclude that the direct (and positive) effect of a tariff reduction, i.e. the decrease in price distortions, more than compensates for its negative (and indirect) effect of reducing incentives of polluters to buy EGS.

Note that this outcome supports the statement of international organizations, such as the WTO and the OECD, calling for trade liberalization in EGS for its potential benefits of increasing access to EGS for non-producing countries. Nonetheless, to have a full understanding of the forces towards this increase in the import demand for EGS along the process of trade liberalization, we need to also analyze the effects of this process on the price of EGS. From equation (4), we can show that

$$\frac{dq_f}{d\tau} = -\left(q_f' + a_f q_f''\right)\frac{da_f}{d\tau_f} - a_f \frac{\partial q_f'}{\partial t_f}\frac{dt_f}{d\tau_f} + 1.$$

According to our above results and from our assumptions, we have that

$$\frac{dq_f}{d\tau} \gtreqless 0 \qquad iff \qquad 1 - a_f \frac{\partial q_f'}{\partial t_f}\frac{dt_f}{d\tau} \gtreqless \left[q_f' + a_f q_f''\right]\frac{da_f}{d\tau}.$$

Hence, contrary to the expectations of the WTO, liberalization of trade in EGS may either leave unchanged or induce an increase or a decrease in the price of such goods and services. Clearly, the outcome notably depends on the convexity of the inverse demand function for EGS. For example, when the abatement demand function is not too convex (specifically, when it is linear or concave), we have that $q_f' + a_f q_f'' < 0$. Therefore, an exogenous reduction in import tariffs on EGS may induce an increase in the price of these goods and services. This increase in the price of EGS is more plausible when the environmental regulator does not significantly adjust downward emission taxes following trade liberalization, when the import demand for EGS increases significantly with tariff reductions, and/or when environmental regulation does not significantly affect the price-elasticity of the pollution abatement demand. Conversely, when the inverse abatement demand function is too convex, i.e. when $q_f' + a_f q_f'' > 0$, then trade liberalization always induces a decrease in the price of EGS. All these observations yield our third proposition.

Proposition 3. *When environmental goods and services are all imported from an imperfectly competitive eco-industry and import tariffs cannot successfully extract rents from this eco-industry, total purchases of these environmental goods and services always increase when trade tariffs fall. However, unless the inverse pollution abatement demand function is too convex, prices of such goods and services may increase with trade liberalization.*

This proposition confirms the view of international organizations which advocate trade liberalization in EGS as a means to promote the growth of environmental markets. Therefore, specifically when the price of EGS increases following the liberalization of their trade, eco-industrial firms and exporting countries of EGS would unambiguously benefit from the globalization of environmental markets.

However, the total level of emissions in the foreign country may increase, decrease, or remained unchanged as tariff reductions occur, according to the following relation:

$$\frac{de_f(x_f,a_f)}{d\tau} \gtreqless 0 \Longleftrightarrow w'(x_f)\frac{dx_f}{dt_f}\frac{dt_f}{d\tau} \gtreqless \epsilon'(a_f)\frac{da_f}{d\tau}.$$

Clearly, as environmental taxation becomes lax when tariff barriers fall, the increase in the total output of the polluting firms will increase the total amount of pollution emitted in the environment. This may counter the positive effect of trade liberalization which increases pollution abatement efforts. This opens up the following proposition.

Proposition 4. *As environmental taxes decrease in importing countries of environmental goods and services following tariff reductions on these goods and services, the potential benefits of trade liberalization in environmental goods and services to promote environmental protection in non-producing countries of these goods and services may not occur.*

Observe that our findings in no way advocate the use of trade barriers on EGS. Instead, they provide some insights as to the main conditions under which trade liberalization in EGS might benefit those countries which rely on external suppliers to deal with their environmental problems. From our perspective, a number of facts need to be considered for the success of trade liberalization in EGS. First, the role of import tariffs on EGS for importing countries of such goods and services in extracting rents from the eco-industry must be pointed out. Second, the consideration by the environmental regulator of this role of import tariffs needs to be recognized. Last, the underlying connection between environmental policy and trade policy related to EGS should be considered in the setting of international trade agreements.

5. Concluding remarks

Inasmuch as trade liberalization in standard goods and services decreases their prices, fewer and lower barriers to trade in EGS should, according to the Doha Ministerial Declaration, translate in greater access of EGS-importing countries to the most efficient, diverse, and least expensive environmental technologies on the global environmental market. Furthermore, this would encourage governments in these countries to set more ambitious environmental objectives. Trade liberalization in environmental goods and services would thereby create new market opportunities for exporters and spur development of globally competitive industries dedicated to environmental improvements (Kennett and Steenblik, 2005).

However, the actual outcome is less straightforward. This paper presents the market power that international eco-industrial firms enjoy as the center of the analysis of the effects of the interplay between trade and environmental policies on the environmental market. Indeed, as a stringent environmental regulation may increase the gap between the price and the marginal production cost of EGS, it may generate rents for the eco-industry. Therefore, when an import tariff on EGS cannot help to sufficiently extract these rents to the eco-industry, the government regulator in an importing country of EGS needs to lower the emission tax level with the aim to minimize the extent of the eco-industry to capture polluting firms' profits.

Our model focused on the effects of an exogenous reduction of EGS import tariffs on the structure of environmental taxation, on the price of EGS and their exchanged quantities, as well as on the quality of the environment. Our results showed that, when the import demand for EGS in a country increases with the stringency of environmental regulation, then a tariff reduction gives rise to a less stringent emission tax. We thus suggested the existence of an interplay between environmental and trade policies with regard to their impacts on the production and pricing of EGS. We found that the imported amount of EGS increases when trade liberalization occurs. Nevertheless, the price of these EGS in the importing country may increase as a result of tariff reductions, while environmental taxation becomes less stringent. In fine, the outcome has an ambiguous result on the quality of the environment in EGS-importing countries. Therefore, our findings contradict the WTO and the OECD's view that trade liberalization in EGS would worldwide promote environmental conservation.

Observe that the interplay between import tariffs and environmental taxes is straightforward in our framework because eco-industrial activities cannot be performed locally in the foreign country. In other words, any marginal increase in the stringency of environmental policy in this country induces an increase in its import demand for EGS. However, if a foreign eco-industry also existed, a more stringent pollution policy would induce either more local production or more imports of EGS. A formal analysis of this more complex case where there is room for bidirectional trade in EGS is beyond this paper.[16]

Our analysis left aside a number of other interesting aspects. First, since the level of import tariffs are, in reality, endogenously determined, an analysis of the optimal combination of trade and environmental policies in each of the trading countries would be of particular interest. Second, it would be appealing to compare the results of marginal and non-marginal trade liberalization. Third, since trade liberalization in EGS could, as suggested in the Doha Ministerial Declaration, mean the elimination of all kinds of tariff and non-tariff barriers, our refection could interestingly be replicated in a framework where environmental markets in both the domestic and foreign countries are integrated as a result of trade liberalization. Next, our analysis could be extended to verify if trade liberalization in EGS to deal with transboundary pollution abatement would have the same effects as in this paper.

Finally, eco-industry representatives often present the globalization of environmental markets as a stimulus of mergers and acquisitions in this industry. According to them, globalization will likely increase the dominance of very large suppliers capable to undertake large overseas contracts. As this would accelerate the process toward a more concentrated and market powerful eco-industry, which is central in the impact of trade liberalization in EGS on the quality of the environment, it would be interesting to analyze the interplay between trade policy targeting EGS, environmental policy, and mergers'

[16]Intuitively, in this case, both countries have incentives to impose import tariffs on EGS to extract rents from their outsider eco-industry. Moreover, their optimal structures of environmental taxation would depend on the effect of emission taxes on the market share of both eco-industries.

activities in the eco-industry. For example, the following questions could be insightful. Would liberalization of trade in EGS give rise to new incentives towards the emergence of national eco-industries - so that the local production of environmental goods and services substantially increases worldwide - ? Or, inversely, would it bring toward a situation with multinational eco-industrial firms producing the bulk of world EGS ? Finally, our analysis could be extended to address the following question: would trade liberalization in EGS to deal with transboundary pollution abatement have the same effects as in this paper? These are some of the issues left for further research.

Appendix

A. Comparative-static analysis for the polluting industry

Differentiating equations (1) and (2) with respect to t_i yields:

$$-C''(x_i)\frac{dx_i}{dt_i} - t_i w''(x_i)\frac{dx_i}{dt_i} = w'(x_i),$$
$$-t\epsilon''(a_i)\frac{da_i}{dt_i} = \epsilon'(a_i).$$

Solving this set of equations by Cramer's rule gives us the following results:

$$\frac{dx_i}{dt_i} = -\frac{w'(x_i)}{C''(x_i)+t_i w''(x_i)},$$
$$\frac{da_i}{dt_i} = -\frac{\epsilon'(a_i)}{t\epsilon''(a_i)}.$$

From our assumptions, we have that $\frac{dx_i}{dt_i} < 0$ and $\frac{da_i}{dt_i} > 0$.

B. Comparative-static analysis for the eco-industry

B.1. Impact of environmental taxation on the equilibrium supply of EGS

Differentiating equations (3) with respect to t_h and (4) with respect t_f respectively gives

$$2q_h'(a_h, t_h)\frac{da_h}{dt_h} + \frac{\partial q_h}{\partial t_h} + a_h q_h''(a_h, t_h)\frac{da_h}{dt_h} + a_h\frac{\partial q_h'}{\partial t_h} = 0,$$
$$2q_f'(a_f, t_f)\frac{da_f}{dt_f} + \frac{\partial q_f}{\partial t_f} + a_f q_f''(a_f, t_f)\frac{da_f}{dt_f} + a_f\frac{\partial q_f'}{\partial t_f} = 0.$$

This implies that

$$\frac{da_h}{dt_h} = -\frac{\frac{\partial q_h}{\partial t_h} + a_h \frac{\partial q_h'}{\partial t_h}}{2q_h'(a_h,t_h) + a_h q_h''(a_h,t_h)}$$
$$\frac{da_f}{dt_f} = -\frac{\frac{\partial q_f}{\partial t_f} + a_f \frac{\partial q_f'}{\partial t_f}}{2q_f'\left(a_f,t_f\right) + a_f q_f''\left(a_f,t_f\right)}.$$

To ensure the existence and uniqueness of the solution of the eco-industry's problem, we assume that $2q_h' + a_h q_h'' < 0$ and $2q_f' + a_f q_f'' < 0$. Combined with our assumptions, this implies that $\frac{da_h}{dt_h} > 0$ and $\frac{da_f}{dt_f} > 0$.

B.2. Impact of environmental taxation on the equilibrium price of EGS

From equations (3) and (4), we have that

$$\frac{dq_h}{dt_h} = -\left[q_h'\left(a_h, t_h\right) + a_h q_h''\left(a_h, t_h\right)\right]\frac{da_h}{dt_h} - a_h \frac{\partial q_h'}{\partial t_h},$$
$$\frac{dq_f}{dt_f} = -\left[q_f'\left(a_f, t_f\right) + a_f q_f''\left(a_f, t_f\right)\right]\frac{da_f}{dt_f} - a_f \frac{\partial q_f'}{\partial t_f}.$$

This is equivalent to

$$\frac{dq_h}{dt_h} \gtreqless 0 \quad iff \quad \left[q_h'\left(a_h, t_h\right) + a_h q_h''\left(a_h, t_h\right)\right]\frac{da_h}{dt_h} + a_h \frac{\partial q_h'}{\partial t_h} \lesseqgtr 0$$
$$\frac{dq_f}{dt_f} \gtreqless 0 \quad iff \quad \left[q_f'\left(a_f, t_f\right) + a_f q_f''\left(a_f, t_f\right)\right]\frac{da_f}{dt_f} + a_f \frac{\partial q_f'}{\partial t_f} \lesseqgtr 0.$$

From our assumptions and the results in appendix (B.1), we can show that $\frac{dq_h}{dt_h} > 0$ always if $q_h\left(a_h, t_h\right)$ is linear or concave in a_h. Similarly, $\frac{dq_f}{dt_f} > 0$ always if $q_f\left(a_f, t_f\right)$ is linear or concave in a_f.

C. Optimal pollution taxes

Totally differentiating (5) with respect to $t_h$and (6) with respect to t_f respectively yields

$$\frac{dW_h}{dt_h} = \left[P_h\left(x_h\right) - C'\left(x_h\right)\right]\frac{dx_h}{dt_h} - G'\left(A_h\right)\frac{da_h}{dt_h} - v\left[w'\left(x_h\right)\frac{dx_h}{dt_h} - \epsilon'\left(a_h\right)\frac{da_h}{dt_h}\right] = 0, \quad \text{(C-1)}$$

$$\frac{dW_f}{dt_f} = \left[P_f\left(x_f\right) - C'\left(x_f\right)\right]\frac{dx_f}{dt_f} - -v\left[w'\left(x_f\right)\frac{dx_f}{dt_f} - \epsilon'\left(a_f\right)\frac{da_f}{dt_f}\right] + \left[\tau - q_f(a_f, t_f)\right]\frac{da_f}{dt_f} - a_f\frac{dq_f}{dt_f} = 0. \quad \text{(C-2)}$$

Substituting (1) and (3) into (C-1), and (1) into (C-2), we respectively get:

$$t_h w'\left(x_h\right)\frac{dx_h}{dt_h} - \left[q_h\left(a_h, t_h\right) + q_h'\left(a_h, t_h\right)a_h\right]\frac{da_h}{dt_h} - v\left[w'\left(x_h\right)\frac{dx_h}{dt_h} - \epsilon'\left(a_h\right)\frac{da_h}{dt_h}\right] = 0, \quad \text{(C-3)}$$

$$t_f w'\left(x_f\right)\frac{dx_f}{dt_f} - v\left[w'\left(x_f\right)\frac{dx_f}{dt_f} - \epsilon'\left(a_f\right)\frac{da_f}{dt_f}\right] + \left[\tau - q_f(a_f, t_f)\right]\frac{da_f}{dt_f} - a_f\frac{dq_f}{dt_f} = 0. \quad \text{(C-4)}$$

Substituting now (2) into (C-3) and (C-4), we respectively have:

$$t_h w'\left(x_h\right)\frac{dx_h}{dt_h} - t_h\epsilon'\left(a_h\right)\frac{da_h}{dt_h} - q_h'\left(a_h, t_h\right)a_h\frac{da_h}{dt_h} - v\left[w'\left(x_h\right)\frac{dx_h}{dt_h} - \epsilon'\left(a_h\right)\frac{da_h}{dt_h}\right] = 0, \quad \text{(C-5)}$$

$$t_f w'\left(x_f\right)\frac{dx_f}{dt_f} - v\left[w'\left(x_f\right)\frac{dx_f}{dt_f} - \epsilon'\left(a_f\right)\frac{da_f}{dt_f}\right] + \tau\frac{da_f}{dt_f} - t_f\epsilon'(a_f)\frac{da_f}{dt_f} - a_f\frac{dq_f}{dt_f} = 0. \quad \text{(C-6)}$$

Solving equations (C-5) with respect to t_h and (C-6) with respect to t_f gives expressions (7) and (8), respectively.

D. Effects of import tariff variations

Differentiating equations (4) and (8) with respect to τ gives

$$\left[2q_f' + a_f q_f''\right] \frac{da_f}{d\tau} + \left[\frac{\partial q_f}{\partial t_f} + a_f \frac{\partial q_f'}{\partial t_f}\right] \frac{dt_f}{d\tau} = 1,$$

$$\left[\frac{dq_f}{dt_f} + a_f \frac{dq_f'}{dt_f} + (t_f - v)\, \epsilon''(a_f) \frac{da_f}{dt_f}\right] \frac{da_f}{d\tau} - \left[w'(x_f) \frac{dx_f}{dt_f} - \epsilon'(a_f) \frac{da_f}{dt_f} + (t_f - v)\, w''(x_f) \left(\frac{dx_f}{dt_f}\right)^2\right] \frac{dt_f}{d\tau} = \frac{da_f}{dt_f}.$$

Solving the above set of equations by Cramer's rule gives the following results:

$$\frac{da_f}{d\tau} = \frac{\left(2q_f + a_f q_f''\right)\frac{da_f}{dt_f} - \left[\frac{\partial q_f}{\partial t_f} + a_f \frac{\partial q_f'}{\partial t_f} + \left(t_f - v\right)\epsilon''\left(a_f\right)\frac{da_f}{dt_f}\right]}{-\left(2q_f + a_f q_f''\right)\left[w'\left(x_f\right)\frac{dx_f}{dt_f} - \epsilon'\left(a_f\right)\frac{da_f}{dt_f} + \left(t_f - v\right)w''\left(x_f\right)\left(\frac{dx_f}{dt_f}\right)^2\right] - \left(\frac{\partial q_f}{\partial t_f} + a_f \frac{\partial q_f'}{\partial t_f}\right)\left[\frac{dq_f}{dt_f} + a_f \frac{dq_f'}{dt_f} + \left(t_f - v\right)\epsilon''\left(a_f\right)\frac{da_f}{dt_f}\right]},$$

$$\frac{dt_f}{d\tau} = \frac{-\left[w'\left(x_f\right)\frac{dx_f}{dt_f} - \epsilon'\left(a_f\right)\frac{dA_f}{dt_f}\right] - \left(t_f - v\right)w''\left(x_f\right)\left(\frac{dx_f}{dt_f}\right)^2}{-\left(2q_f + a_f q_f''\right)\left[w'\left(x_f\right)\frac{dx_f}{dt_f} - \epsilon'\left(a_f\right)\frac{dA_f}{dt_f} + \left(t_f - v\right)w''\left(x_f\right)\left(\frac{dx_f}{dt_f}\right)^2\right] - \left(\frac{\partial q_f}{\partial t_f} + a_f \frac{\partial q_f'}{\partial t_f}\right)\left[\frac{dq_f}{dt_f} + a_f \frac{dq_f'}{dt_f} + \left(t_f - v\right)\epsilon''\left(a_f\right)\frac{da_f}{dt_f}\right]}.$$

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