Tariff reforms in the presence of pollution

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Abstract
A number of countries are considering, mainly as part of their obligations under current treaties, domestic actions to internalize the social cost of pollution. One of the major obstacles, however, in those countries is the fear of jeopardizing their competitive position in world markets. A policy that has been repeatedly proposed to deal with this challenge is a tariff mitigating any distortions arising from cross-country differences in environmental policy. Such unilateral actions are the focus of this paper. It is argued that if a country set its pollution taxes optimally, cooperatively or non-cooperatively, there exist unilateral tariff reforms that improve global welfare

Keywords: *Environmental taxation; Tariff reforms; BTAs; International trade; Pareto efficiency; Pareto improving reforms; Climate change.*
JEL classification: *H20; F18.*

Introduction

The Intergovernmental Panel on Climate Change (2014) predicts that under "business as usual" the global mean temperature over the next century will increase by between 3.7^{o}C and 4.8^{o}C compared to pre-industrial levels. The potential consequences, both physical and economic, of such considerable temperature increases are likely to be catastrophic (Stern (2006) and Jones et al. (2012)). It is reckoned that to reduce the adverse impact of dangerous levels of atmospheric greenhouse gases concentration, it would be required, collectively, to slow and then cut global GHG emissions by a substantial 40-70 percent by 2050, compared to 2010 levels and GtCO2eq near to zero (IPCC 2014).[2] This along with the asymmetric impact

[1] An earlier version of this paper was part of my PhD thesis conducted at the University of Exeter. I am grateful to the faculty of Economics, University of Exeter, for their support. Special thanks to Christos Kotsogiannis for introducing me to the issue of border tax adjustments and for his helpful comments and suggestions. I also thank Pascalis Raimondos-Møller, Ben Zissimos and Michael Michael for their comments and suggestions as well as the participants in the ETSG 2013 and the Second Environmental Protection and Sustainability Forum: Towards Global Agreements on Environmental Protection and Sustainability 2015.

[2] For recent—and insightful—surveys on the issue see Chen and Woodland (2013) and Jones et al. (2013).

of climate change and the unboundary nature of emissions reveals the need for international cooperation.[3] But such cooperation is not easy to be achieved, as was seen in the Kyoto or the Copenhagen Protocol.

In response to this challenge, a number of countries are considering, mainly as part of their obligations under current treaties, domestic action to address climate change. One of the major obstacles, however, in those countries towards taking such action, is the concern that it may disadvantage domestic industries relative to producers in countries that do not undertake similar actions. At the heart of this issue lies a classic free-rider problem. Since the reduction of greenhouse gases is a global public good each country would prefer the others to cut emissions thereby avoiding bearing the cost.

A unilateral policy action that has been repeatedly proposed to deal with this challenge could include a provision that forces goods entering the home market to internalize the cost of pollution. A measure that does this is a border-tax-adjustments (BTAs) on imported goods that levels the playing field between domestic producers that face costly climate measures and foreign producers that face very few. A BTA would put a charge (in the form of a carbon tax) on imported goods equivalent to what these goods would have had to be charged if they had been produced domestically. In the case of exported goods the scheme rebates any payment of carbon taxes to exporters. By doing this it preserves mitigation of emissions without affecting the international competitiveness of carbon-intensive sectors thereby mitigating carbon leakage incentives (that is; mitigating the incentive of carbon-intensive sectors to relocate production to countries with low environmental standards). [4]

There are many issues related to the legality, implementation and effectiveness of the BTAs as a carbon pricing policy (Condon and Ignaciuk, 2013; Holmes et al., 2011; Kortum and Weisbach, 2016; OECD, 2016; Trachtman, 2017). As it has been advocated by many academics and policymakers the legal status of BTAs is unambiguous (Cosbey et al., 2012; Hillman, 2013; Pauwelyn, 2012). According the WTO provisions countries can adopt non-discriminatory "harmonizing" carbon tariff as a straight forward extension of the domestic climate policy provided that the tariff imposed on imported "like" goods does not exceed the corresponding domestic tax[5] and the rebate of tax on export does not exceed the tax previously paid.[6] BTAs are also justifiable under the environmental exceptions in Article

[3]Keen and Kotsogiannis (2014) research the interaction between environmental and trade policies from a cooperative perspective and the characterization of each policy as a Pareto efficient instrument. Turunen-Red and Woodland (2004) argue that multilateral agreements on international trade and environmental policy could be welfare improving.

[4]For an analysis on BTAs (as Pareto efficient devices) see Keen and Kotsogiannis (2014).

[5]GATT Article III:2. "The products of the territory of any contracting party imported into the territory of any other contracting party shall not be subject, directly or indirectly, to internal taxes or other internal charges of any kind in excess of those applied, directly or indirectly, to like domestic products. Moreover, no contracting party shall apply internal taxes.... to imported or domestic products in a manner contrary to the principles set forth in paragraph 1." The reference in Art. III:1 states that: "internal taxes should not be applied to imported or domestic products so as to afford protection to domestic production."

[6]GATT Article XVI: "The exemption of an exported product from duties or taxes born by the like product when destined for domestic consumption, or the remission of such duties or taxes in amounts not in excess of those which have accrued, shall not be deemed a subsidy."

XX of GATT.[7] On contrary, the implementation and effectiveness of BTAs raises a lot of concerns with the main one being the use of BTAs as a trade manipulation and protection mechanism (Holmes et al., 2011; Moore, 2010). Other issues relate to the set of goods and sectors to be covered by the BTAs (Cosbay et al., 2012) and the monitoring and administrative cost, as goods may be imported from countries that do not monitor their GHG emissions (Pauwelyn, 2012). Despite these concerns BTAs remain at the centre of the environmental debate. The Paris Agreement implies the absence of consensus about the adequacy of countries' climate efforts while at the same time requires countries to increase their mitigation efforts over time. With countries being able to judge efforts by others as "inadequate" the pressure for implementing BTAs to bridge these asymmetries, correcting for their effects on competitiveness and carbon leakage, will be increased.[8]

The study of unilateral governments' actions has not been neglected from the trade and environmental literature. The main body of this literature focuses on the identification of the first and second best optimal policy level of unilateral policy instruments; less attention has been paid on reforms of policy instruments and their effect on welfare.[9] The first and second best optimal is key issue in the analysis of Markusen (1975), Baumol and Oates (1988), Krutilla (1991) Hoel (1996), Copeland (1996), Beghin et al. (1997), Hatzipanayotou et al (2002, 2008), Keen and Kotsogiannis (2014) for open economics in the presence of pollution externalities. Within this context they identify the optimal level of policy instruments when environmental and trade policies are available focusing also on the case of only one policy tool being available with the other one being distorted away from its optimal level. Less attention has being paid to unilateral policy reforms. Copeland (1994) and Beghin et al. (1997) consider such reforms for environmental and trade policy instruments in the context of small open economy, establishing the existence of unilateral reforms that deliver potential Pareto improvement. In particular, it is argued that reforms of pollution and trade taxes and quotas, in proportion to their deviation from their optimal level, are welfare improving. In a similar context Neary (2005) identifies the first and second best optimal level of emissions binding standards, emission taxes and trade tariffs. He also examines the welfare effects of unilateral reforms of the available policy instruments. Hatzipanayotou et al (2008), within a model of two small open economies with two goods and cross-border pollution, identify the effect of cross-border pollution and terms of trade changes on Nash emission taxes, emission levels and welfare arguing that under certain circumstances they can be welfare increasing.

Although the characterization of tariffs (BTAs) as a Pareto efficient instrument is well understood,[10] it is not entirely clear whether, starting from a distorting initial equilibrium

[7]GATT, Article XX, Paragraph (b) "necessary to protect human, animal or plant life or health" and Paragraph (g): "relating to the conservation of exhaustible natural resources"

[8]For more detailed discussion on the Paris Agreement see Cosday, (2016) and Hawkins (2016).

[9]As it is known form the literature on distortions (e.g. Bhagwati, 1971), first best policy requires at least two instruments e.g. trade taxes and emission taxes. Each instrument directly affects its corresponding economic sector (trade taxes affect trade flows, emission taxes affect emissions). However each instrument indirectly affects the other sectors. While in the second best optimal case, at least one of the available policy instruments is constrained away from its optimal level, the remaining ones must take account of all economic activities.

[10]see among others Markusen (1975), Baumol and Oates (1988), Krutilla (1991) Hoel (1996), Copeland

(in emission levels), there exist tariff reforms undertaken unilaterally by a country that increases global welfare. And this is the objective of this paper. It will be shown that, with the environmental policy set at its optimal non-cooperative or cooperative level, there exists a tariff reform—and one that changes tariffs equi-proportionately— that maximizes aggregate welfare. Such reform are commonly used in the international trade and environmental literature as in Baumol and Oates (1988), Copeland (1994) and Neary (2006). This paper deviates from these researches as it allows for transboundary pollution externalities and captures also the foreign country's responses to home country's fiscal policy distortions. Also by focusing on a small open economy we are able to focus clearly, compared to the case of large open economies, on the effects of trade distortions on environmental quality. Interestingly the source of inefficiency of the pollution distortion is coming only through the home country's production which consequently affects foreign country's utility.[11]

The rest of this paper is organized as follows. Section describes the model. Section discusses the existence of welfare increasing tariff reforms in the presence of optimal non-cooperative pollution taxes. Section introduces welfare increasing tariff reforms in the presence of optimal cooperative pollution taxes while Section summarizes the results and discusses their policy relevance.

Description of the model

The framework is a standard model of international trade with two countries labeled "home" and "foreign". Home and foreign country's variables are indexed by lower- and upper-case letters, respectively. The economy is a perfectly competitive with home country being a small open one, thus it cannot affect international prices, w.[12]

In each country there are N tradeable commodities. The first traded commodity is used as the numeraire good, with its home and foreign prices being normalized to unity. Throughout the analysis it will be assumed that the numeraire good is untaxed. Pollution is modeled as a by-product of production in the sense that production generates some pollutant, denoted by the N-vector z, for the home, and Z for the foreign country. Total emissions in the home (foreign) country denoted by $k(K)$ are given by $i'z$ $(i'Z)$, where i is the N-vector of 1s (and a prime denotes transposition).

(1996), Neary (2005), Keen and Kotsogiannis (2014) Tsakiris et al (2014)

[11] This is a realistic scenario as most developed countries considering to implement BTAs cannot affect the international price of most of the goods they trade. Despite the fact that BTAs have not been implemented by any country until now they remain a topical issue, see Condon and Ignaciuk (2013), Kortum and Weisbach (2016). Although, as is argued by Cernat (2010) "in pursuit of green growth the EU must avoid protectionism", over time politicians have revisited the idea of BTAs which is in line with the EU Emission Trading System (EU ETS) Directive (see among others Helm, 2014; Hontelez, 2007 and Foure et al, 2013) . Similar provisions were made by the US Federal cap and trade scheme under the American Clean Energy and Security Bill (Waxman-Markey), although it was never passed into law (for recent discussion of US climate policy see Sandbu, 2017).

[12] The current framework does not impose any restrictions on the size of the foreign country.

Pollution is transboundary and given by[13]

$$k = K = i'z + i'Z \ . \tag{1}$$

In each country there is a representative consumer with preferences represented by the expenditure function $e(u, k, p)$ $(E(U, K, P))$ that gives the minimum expenditure required to achieve utility $\bar{u}$ $(\bar{U})$ given pollution k (K) and prices p (P) respectively for each country.

$$\begin{aligned} e(p, u, k) &= \min_x \{p'x : u(x, k) \geq \bar{u}\} \\ E(P, U, K) &= \min_x \left\{P'X : U(X, K) \geq \bar{U}\right\} \quad , \end{aligned} \tag{2}$$

with, as an envelope property, e_p (E_p) being the vector of compensated demands and e_k (E_K) the consumer's marginal willingness to pay for pollution reduction in terms of the private good. Notice, for later use that, $e_k > 0$ $(E_K > 0)$ since pollution is a "public bad"; a unit of extra consumption of pollution requires by the consumer a positive compensation in terms of the private good.

Home country imposes sector-specific pollution taxes, given by the N-vector s. All collected revenues are returned to the consumer in a lump-sum fashion.

The private sector in the home country is perfectly competitive and characterized by the revenue function

$$r(p, s, v) = \max_{y,z}\{p'y - s'z : (y, z) \in \tau(v)\} \ , \tag{3}$$

where $\tau(v)$ is the home country's technology set, v is the vector of endowments, and y denotes the (net) output of tradeable goods. The revenue function in (3) gives the maximum revenues generated for given prices p and pollution taxes s. It has the standard properties: It is a convex function, homogeneous of degree one in p and s and (assumed to be) twice continuously differentiable.[14] Given the properties of the revenue function, the matrices r_{pp} and r_{ss} are both positive semi-definite matrices.[15]

Hotelling's lemma implies that, the output vector is given by

$$y = r_p(p, s) \ \ , \tag{4}$$

whereas the vector of emissions (associated with the production of the N tradeable goods) is give —as an envelope property from (3)— by

$$z = -r_s(p, s) \ \ . \tag{5}$$

Production in the foreign country is described by

$$R(P, S, V) = \max_{Y,Z}\{P'Y - S'Z : (Y, Z) \in T(V)\} \ . \tag{6}$$

[13]Notice that one can also introduce (the degree of) externalities across countries. This, however, would add no additional insights.

[14]Notice that implicit in (3) is that the private sector can abate environmental discharges by altering production patterns.

[15]The endowment vectors, being fixed, are being suppressed from what follows.

Following (6), as an envelope property, the output and the emissions vectors are defined, respectively, by

$$Y = R_p(P,S) \quad ; \quad Z = -R_s(P,S) \ , \tag{7}$$

where P is the foreign country's price vector of the tradeable goods.

The home country uses trade taxes (or subsidies if they are exported) —denoted by the N-vector t— on the tradeable goods with any revenues being returned to the consumer in a lump-sum fashion.

Given the vector of pollution taxes and tariffs, the equilibrium for this economy, assuming it exists, is characterized by

$$e(u,k,p) = r(p,s) + t'(e_p(u,k,p) - r_p(p,s)) + s'z \ , \tag{8}$$

$$E(U,K,P) = R(P,S) + SZ, \tag{9}$$

$$p = P + t \ , \tag{10}$$

$$P = w \ , \tag{11}$$

$$k = K = i'z + i'Z = -i'r_s(p,s) - i'R_s(P,S) \ . \tag{12}$$

Equations (8) and (9) represent the budget constraint of the consumer of the home and the foreign country, respectively: It simply says that (for the home country) expenditures given by $e(u,k,p)$ are equal to GDP, given by $r(p,s)$, plus the pollution-tax and the tariffs revenues, given by $s'z$ and $t'(e_p(u,k,p) - r_p(p,s))$. Similarly for the foreign country—in the absence of trade taxes— expenditures $E(U,K,P)$ are equal to GDP $R(P,S)$ plus the pollution tax revenues. Equation (10) stands for the home country's prices which are equal to the foreign country's goods prices plus the imposed tariffs on imported goods. Finally, equation (11) is the foreign country's goods prices which are equal to international ones.

Perturbing equation (12), after making use of the fact that—following[16] $dw = 0$—$dp = dt$ one obtains[17]

$$dk = dK = -i'r_{sp}dt - i'r_{ss}ds \ . \tag{13}$$

Totally differentiating equation (8)—after making use of (4), (13) and the fact that $dp = dt$ and also $dP = 0$—one obtains

$$e_u(1 - t'm)du = [(e_k i' - t'e_{pk} i' - s')\, r_{sp} - t'\lambda]\, dt + [(e_k i' - t'e_{pk} i' - s')\, r_{ss} - t'r_{ps}]\, ds \ , \tag{14}$$

where $1 - t'm > 0$, with $m = e_{pu}/e_u > 0$, and $\lambda = r_{pp} - e_{pp}$ is a positive semi-definite matrix of home excess compensated supplies.[18]

Equation (14) shows, clearly, that home country welfare depends on a number of distortions. In particular:

[16] Recall that this is small open economy.

[17] Equation (13) shows the limitation of fixed international prices w. If international prices could be affected by home country's tariffs and pollution taxes, the home country would be able to affect foreign production directly via international prices w, since they are functions of domestic instruments. To see this notice that, following (6), $dK = -i'R_{SP}dw$. Any change in s or t would affect w and so, in turn, K.

[18] $e_u(1 - t'm)$ gives the change in the real income, deflated by the tariff multiplier, Neary (2006). The fact that $1 - t'm > 0$ relates to the stability of the equilibrium (and to the Hatta normality condition).

- The term $e_k i' - t' e_{pk} i' - s'$ gives the deviation of the marginal damage, in the home country, from the pollution-tax vector s. With trade taxes, an increase in pollution affects consumers through two effects: A direct one, given by $e_k i'$, and an indirect one, given by $t' e_{pk} i'$, through the trade distortions and so via a change in the compensated demands. If the compensated demands fall because of an increase in pollution, and so $e_{pk} < 0$, then the trade distortion is exacerbated by the pollution.

- The term $t'\lambda$ which gives the effect of changes in the import demand as a consequence of the change in tariffs.

Similarly, pollution taxes have a number of effects on welfare.

- The term $e_k i'$ gives the direct effect (a reduction of pollution which represent a welfare gain) of the tax on pollution.

- The term $t' e_{pk} i'$ gives the indirect effect through the trade distortion.

- The term $t' r_{ps}$ gives the effect of pollution taxes on welfare through tax revenues (since imports change as a consequence of changes in the policy instrument).

Tariff reforms in the presence of non-cooperative environmental policy

The balance of the effects described above define, according to equation (14), the optimal policies of the home country.[19] Clearly, and in the absence of tariffs, the preceding discussion suggests that the home country will set pollution taxes, at the optimum level $e_k i = s$. Indeed this is the case. To see this set $t = 0$ and $dt = 0$ in (14) to obtain

$$e_u du = (e_k i' - s')\, r_{ss} ds \ , \tag{15}$$

and so optimality, from the home country's perspective, dictates that the optimal pollution tax is given by —given that r_{ss} is (assumed to be) invertible—$s = e_k i$.

Optimal second best environmental policy for the home country dictates that it sets pollution taxes equal to the consumer's marginal willingness to pay for pollution reduction. The fact that home country sets $s = e_k i$ is intuitive: Since the home country cannot affect international prices and, therefore, pollution in the foreign country it sets the marginal willingness to pay for a reduction in pollution at home e_k equal to the pollution-tax s.[20]

[19] With each policy instrument directly affecting its corresponding economic sector (tariffs affect trade flows whereas pollution taxes affect emissions), it is intuitive that the first best optimal policy requires the use of two policy instruments: tariffs targeting trade flows and pollution taxes targeting the externality directly. Under second best optimal policy either there is only one policy instrument available or there are two but one has been set at inefficient levels. For contributions see, among others, Markusen (1975), Krutila (1991), Hoel (1996), Neary (2006), Keen and Kotsogiannis (2014).

[20] One, of course, might ask whether, starting from an initial situation in which $e_k \neq s$, a pollution tax reform that increases utility in the home country can be implemented. The answer to this is in the affirmative. Consider, for instance, the reform that changes s equiproportionally to its difference from the marginal external damage of pollution that is, $ds = (e_k - s)\, da$ where a is a scalar and $da > 0$. In this case

The analysis turns next to the search for Pareto improving tariff reforms when the home country set its pollution taxes at their second best optimum level.

Suppose now that the home country imposes pollution taxes optimally following (15) and the foreign country's pollution taxes S are fixed at arbitrary levels. Perturbing (9), for fixed pollution tax vector s and S, with $dw = 0$ and using equation (13), one obtains

$$E_U dU = E_K i' r_{sp} dt \ . \tag{16}$$

As can be seen from (16) foreign welfare is affected by the home country's tariffs but, interestingly, not because tariffs have a price effect on foreign demand but simply because they affect production at home and so pollution in the foreign country (the term $i' r_{sp}$).[21] What (16) also shows is the possibility that the foreign country might benefit from a tariff reform in the home country.[22]

Aggregate welfare,[23],[24] following from (14) and (16) with pollution taxes set to optimum, is given by

$$\delta du + \Delta dU = \left[\left(E_k i' - t' e_{pk} i' \right) r_{sp} - t' \lambda \right] dt \ , \tag{17}$$

where $\delta \equiv e_u \left(1 - t'm\right)$ and $\Delta \equiv E_U$. It is now easy to see that the optimal tariff that maximizes global welfare is given by

$$t'\left(s\right) = \left(E_k i' - t' e_{pk} i' \right) r_{sp} \lambda^{-1} \ , \tag{18}$$

where $t\left(s\right)$ denotes the dependence of the optimal tariff on pollution distortions. What (18) emphasizes is that it is not only distortions via trade (in the sense of changes in the home country's compensated demands, $e_{pk} i' r_{sp} \lambda^{-1}$) that the optimal tariff should account for, but also the foreign country pollution distortions ($E_k i' r_{sp} \lambda^{-1}$), that affect foreign (and so global) utility. Notice that if $r_{sp} = 0$, then the optimal tariff, from a world welfare perspective, is zero: The point here being that tariffs cannot affect production decisions at home and, therefore, should not be used; *free trade* is optimal.

The question that now arises is to what extent one can construct a tariff reform that raises global welfare.[25] This is to what we now turn. To answer this it will help re-writing—using

(15) reduces to

$$e_u \left(1 - t'm\right) du = \left(e_k - s\right)' r_{ss} \left(e_k - s\right) da > 0$$

where the inequality sign following from the fact that r_{ss} is a positive semi-definite matrix. This reconfirms the result in Copeland (1994), p.51.

[21] Notice that—as alluded to earlier—if the home country's emissions do not respond to prices, and so $r_{sp} = 0$, then the home country's tariffs will not affect foreign welfare.

[22] This will be the case if, for instance, tariffs change according to $dt = E_k i' da$ where a is a scalar. In this case (16) reduces to $E_U dU = E_k i' r_{sp} E_k i' da$. The welfare sign of this depends on the structure of the matrix r_{sp}, which cannot be signed without additional assumptions on the structure of technology (see Copeland, 1994), and on the direction of da. All the reform requires is that da taken the same sign of r_{sp}.

[23] The home country undertakes a global perspective as its actions aim to tackle pollution and not rent seeking, as in Copeland (1996). Also a tariff reform that is aggregate welfare increasing will be easier to be justified under the WTO principles.

[24] Implicitly, behind this is the existence of lump sum transfers between countries and the welfare of each country is equally weighted.

[25] As the home country sets its environmental policy at the second best optimal non-cooperative level it does not internalize the externality to the foreign country.

(18)—aggregate welfare in (17) as

$$\delta du + \Delta dU = [t\,(s) - t]'\,\lambda dt\ . \tag{19}$$

Consider now the scenario of moving tariffs towards their Pareto efficient level in the sense that

$$dt = [t(s) - t]\,da\ , \tag{20}$$

with $da > 0$. Substituting (20) into (19) we have that

$$\delta du + \Delta dU = [t\,(s) - t]'\,\lambda\,[t(s) - t]\,da > 0\ , \tag{21}$$

where the inequality follows from the fact that λ is a positive semi-definite matrix (and $da > 0$). This simply says that if the optimal tariff that maximizes global welfare $t(s)$ is above the existing one t it should be increased. If on the other hand $t\,(s) < t$ then it should be reduced. To emphasize:

Proposition 1. *Starting from any arbitrary tariff distorted equilibrium, with $t \neq t\,(s)$, and initial pollution taxes set at their second best optimal non-cooperative level $s = e_k i$, then a tariff reform in the sense of (20) is Pareto improving.*

Proposition 1 can be seen as a generalization of Copeland (1994).[26] The difference of the present analysis to the one in Copeland (1994) is that here the home country takes a global perspective (as it also receives utility from the foreign country).[27] Intuitively, Proposition 1 states that the source of inefficiency, given that international prices are fixed, is not the foreign country but the home one. It is the production of the home country that the reform should be accounting for, and not by how much the foreign country produces and so pollutes.

Though the result of Proposition 1 is, arguably, insightful it seems to be rather restrictive as it is assumed that pollution taxes have been determined under the assumption that tariffs are zero. I now relax this assumption. Suppose that optimal pollution taxes are set at their optimal first best level and so—following (14)—at

$$s' = e_k i' - t' e_{pk} i' - t' r_{ps} r_{ss}^{-1}\ . \tag{22}$$

Making use now of the fact that $r\,(p, s)$ is homogeneous of degree one in p and s we have (following (14)) that[28]

$$e_u\,(1 - t'm) = t' e_{pp} dt\ . \tag{23}$$

Suppose now that tariffs change according to $dt = -tda$ for some $da > 0$.(and so uniformly). Then

$$e_u\,(1 - t'm) = -t' e_{pp} t da > 0\ , \tag{24}$$

[26] For more detailed analysis on the effects of equiproportional distortions on welfare see Dixit (1985) and, in a similar context, Baumol and Oates (1988).

[27] This, as briefly touched upon in the introductory section, relates to border tax adjustments. It is the direction of the reform, and not of the determination of the actual tariff that is the concern here.

[28] This implies that $r_{pp}p + r_{ps}s = 0$ and $r_{sp}p + r_{ss}s = 0$, and so $r_{ps}r_{ss}^{-1}r_{sp} = r_{pp}$.

where the inequality follows from the fact that e_{pp} is a negative semi-definite matrix.
Turning now to global welfare which, following from (16) and (23), is given by

$$\delta du + \Delta dU = \left(E_k i' r_{sp} + t' e_{pp}\right) dt \ . \tag{25}$$

the optimal tariff is given by

$$t'(s) = -E_k i' r_{sp} e_{pp}^{-1} \ , \tag{26}$$

which upon close inspection—and in contrast to equation (18)—it reveals that it is independent of the home country's pollution distortion. This is intuitive as the home country takes into account its own pollution distortion by setting its pollution taxes optimally according to (22).

Consider now an equiproportional movement of tariffs towards their optimum level, in the sense that

$$dt = -\left[t - t(s)\right] da \ , \tag{27}$$

for a scalar $da > 0$. Global welfare can then be written as

$$\delta du + \Delta dU = -\left[t - t(s)\right]' e_{pp} \left[t - t(s)\right] da > 0 \ . \tag{28}$$

So we have that:

Proposition 2. *Starting from any arbitrary tariff distorted equilibrium, with $t \neq t(s)$, and assuming that pollution taxes are set at their first best optimal non-cooperative level, then a home country's tariff reform of the form of (27) is Pareto improving.*

Tariff reforms in the presence of cooperative environmental policy

Suppose now that the home country, restricted by an environmental agreement, is obligated to set its pollution taxes cooperatively, maximizing the aggregate welfare[29] then, the arising question is weather we can identify a Pareto-improving tariff reform.[30] The aggregate welfare is given by[31]

$$\begin{aligned}\delta du + \Delta dU = &\left[\left(e_k i' - t' e_{pk} i' - s'\right) r_{sp} - t'\lambda\right] dt \\ &+ \left[\left(e_k i' - t' e_{pk} i' - s'\right) r_{ss} - t' r_{ps}\right] ds \\ &+ E_k i' r_{sp} dt + E_k i' r_{ss} ds \ \ ,\end{aligned} \tag{29}$$

where $\delta \equiv e_u\left(1 - t'm\right)$ and $\Delta \equiv E_U$. By setting its pollution taxes in a cooperative fashion, the home country should take into account the sum of damages $e_k i + E_k i$, that a marginal

[29] This can be justified by the UNFCCC principle of "common but differentiated responsibility" (United Nations Framework Convention on Climate Change; Principle 1 of Article 3).

[30] An example of this case would be a small European country committed to undertake mitigation measures irrespective of action elsewhere—such policies include the 2020 climate & energy package, 2030 climate & energy framework—and eligible, under the WTO regulation, to apply tariffs in the form of BTAs.

[31] As previously, we allow for unconstrained lump sum transfers between countries and the welfare of each country is equally weighted.

emission causes in all countries, both to itself and the other country. To see this set $t = 0$ and $dt = 0$ in (29) to obtain

$$e_u du + E_U dU \ = \left[\left(e_k i' + E_k i' - s' \right) r_{ss} \right] ds \quad , \tag{30}$$

and so from the aggregate perspective, optimal pollution taxes—given that r_{ss} is (assumed to be) invertible—are given by $s = e_k i + E_k i$.

Second best optimal cooperative policy dictates that the home country's pollution taxes should be uniform within the country and equal to the aggregate consumer's marginal willingness to pay for pollution reduction. This reconfirms the result of Keen and Kotsogiannis (2014): Moving along the world's second-best utility possibility frontier requires that the home country sets its pollution taxes in each sector so as to equate the value of income loss that this causes itself, given by s, to the sum of the damages $e_k i + E_k i$, that a marginal emission causes in all countries, both to itself and the other country.

Setting the home country's pollution taxes at their second best cooperative optimum level aggregate, welfare becomes

$$\delta du + \Delta dU = - \left[t' e_{pk} i' r_{sp} + t' \lambda \right] dt \ . \tag{31}$$

Following from equation (31) the tariff that maximizes global welfare is $t'(s) = -t' e_{pk} r_{sp} \lambda^{-1}$. The fact that the optimal tariff is not accounting for the foreign country's pollution distortions is intuitive: As the home country sets its environmental taxes in a cooperative fashion it internalizes the externality and its effects on the foreign country's consumer.[32] Rearranging the terms of equation (31) we obtain

$$\delta du + \Delta dU = \left[t'(s) - t' \right] \lambda dt \quad ,$$

[32]Notice that the optimal tariffs from the home country's perspective, setting its environmental taxes cooperatively, are given by

$$e_u (1 - t\acute{} m) du = [(-E_k i\acute{} - t\acute{} e_{pk} i\acute{}) r_{sp} - t\acute{} \lambda] dt, \tag{32}$$

$$t\acute{}(s) = -(E_k i\acute{} + t e_{pk} i\acute{}) r_{sp} \lambda^{-1},$$

this is symmetrical to the cooperative second best optimal tariffs when the home country sets its pollution taxes non-cooperative, equation (18). The difference between the two lies in the sign of the effect of home country's pollution distortion on foreign country ($E_k i' r_{sp} \lambda^{-1}$). This is due to the fact that by setting its pollution taxes cooperatively home country takes into account the damages that a marginal emission causes to the foreign country's consumer.

Rearranging the terms of (32) home country's welfare becomes

$$e_u (1 - t\acute{} m) du = \left[t\left(s \right) - t \right]' \lambda dt \ .$$

Considering now a tariffs reform that moves tariffs towards their Pareto efficient level $dt = [t(s) - t] \, da$,with $da > 0$— given that λ is a positive semi-definite matrix— home country's welfare increases

$$e_u (1 - t\acute{} m) du = \left[t\left(s \right) - t \right]' \lambda \left[t(s) - t \right] da \geq 0 \ .$$

where $t'(s) = -t' e_{pk} r_{sp} \lambda^{-1}$. Considering now a uniform reform of tariffs such that

$$dt = [t(s) - t]\, da, \tag{33}$$

with $da > 0$. If the home country implements a reform of (33), global welfare increases

$$\delta du + \Delta dU = [t(s) - t]\,' \lambda\, [t(s) - t]\, da > 0. \tag{34}$$

The inequality follows from the fact that λ is a positive semi-definite matrix (and $da > 0$). To emphasize:

Proposition 3. *Starting from any arbitrary tariff distorted equilibrium, with pollution taxes set at their second best optimal cooperative level $s = e_k i + E_k i$, then a tariff reform in the sense of (33) is Pareto-improving.*

Proposition 3 differs from Proposition 1 as the home country's tariff reform (33) does not account for the home country's pollution distortions ($E_k i' r_{sp} \lambda^{-1}$) that affect the foreign country's consumer. This is due to the fact that the home country's cooperative pollution taxes take into account the damages, $E_k i$, a marginal emission causes to the foreign country's consumer. Proposition 3 suggests that the reform should account for the home country's pollution distortions to its own consumer as well as the tariff effect on its own production and through that pollution.

Turning now to the search of tariff reforms with the environmental taxes set at their first best cooperative level which, following from equation (29), are given by

$$s' = e_k i' + E_k i' - t' e_{pk} i' - t' r_{ps} r_{ss}^{-1}\,. \tag{35}$$

Equation (35) implies that the first best cooperative pollution taxes should account not only for the damage that the marginal emission causes to the home and foreign country's consumer but also for the level of the imposed tariff weighted by the effect of the marginal emission on compensated demand ($t' e_{pk}$) as well as the changes on tariff revenues ($t' r_{ps} r_{ss}^{-1}$) due to the effect of the pollution taxes on production.

Setting now the pollution taxes at their first best cooperative level, it is straightforward to verify that cooperatively free trade is optimum. Since the home country cannot affect international prices and so production capabilities of the foreign country and it takes into account the damage to the foreign country's consumer by setting its environmental taxes at their cooperative first best optimal level.[33]

[33] Notice that the optimal non cooperative tariffs—setting pollution taxes to their optimal first best cooperative level— are given by

$$e_u(1 - t'm)du = \left(-E_k i' r_{sp} e_{pp}^{-1} + t'\right) e_{pp}^{-1} dt\,,$$

$$t'(s) = E_k i' r_{sp} e_{pp}^{-1}\,.$$

Optimality dictates that the non cooperative tariffs should account for the tariff effect on home country's

Aggregate welfare, following from (29) with pollution taxes set at their first best cooperative level, is given by

$$\delta du + \Delta dU = \left(t' r_{ps} r_{ss}^{-1} r_{sp} - t'\lambda\right) dt \ ,$$

which due to the fact that $r(p, s)$ is homogeneous of degree one in p and s becomes

$$\delta du + \Delta dU = t' e_{pp} dt \ .$$

Since e_{pp} is a negative semi-definite matrix there exists increasing welfare tariff reform that reduces the tariffs proportionate, $dt = -t da$ for some $da > 0$. Then

$$\delta du + \Delta dU = -t' e_{pp} t da > 0 \ ,$$

Proposition 4. *Starting from any arbitrary tariff distorted equilibrium, $t \neq 0$, and initial pollution taxes set at their first best optimal cooperative level , then a tariff reform proportional to the initial tariffs level is Pareto-improving.*

Proposition 4 generalizes the results of Copeland (1994) and Neary (2006) taking into account the transboundary nature of pollution and considering cooperative first best allocation of environmental taxes. Similar to the previous results Proposition 4 suggests that the source of inefficiency is the home thus the reform should account only for the home country's production.

Concluding remarks

This paper has investigated the existence of, starting from any arbitrary tariff distorted equilibrium, Pareto improving tariff reforms (of a particular type). It has shown that for a small open regulating economy, and in the presence of transboundary pollution, the source of inefficiency of the environmental quality is driven only through the level of production of the home country. It is this production that the home country's tariff reform targets to reduce and this is true in the presence of either cooperative or non cooperative, first or second best, pollution taxes. This contradicts the underlying idea of BTAs that they are global welfare increasing due to the response—through production reform—of the country with the weaker environmental regulation (see Gros, 2009; Sanctuary, 2013). Since the country implementing the BTAs cannot affect international prices, the reform targets the production of the home country which not only benefits the home country (by having less emissions) but also benefits the foreign country through a reduction in harmful emissions.

The limitations of the paper suggest avenues for future research. International prices have been kept fixed and as a consequence the home country cannot influence foreign production abroad. It would be interesting to allow for the home country to be a large open economy (as in Turunen-Red and Woodland, 2004; Keen and Kotsogiannis, 2014) and, therefore, be

emissions and so foreign country's consumer, weighted by their effect on home country's compensated demand. The sign of optimal tariffs depends on the pollution intensity of home country's production r_{sp}, (for more detailed discussion on the sign of r_{sp} matrix see Neary, 2006). Considering now a tariff reform that moves tariffs proportionally towards their optimum level, $dt = [t(s) - t]\, da$ for some $da > 0$,—given that e_{pp} is a negative semi-definite matrix—home country's welfare increases.

able to influence the terms of trade (and the comparative advantage in the production of goods) of the foreign country. This will be consistent with the current rhetoric in favour of border tax adjustments.

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