Multilateral Reforms of Trade and Environmental Policy of an Environmental Union

Catia Montagna,† Avanti Pinto ∗ & Nikolaos Vlassis†

31st January 2019

Early Version

Abstract

This paper analyses environmental and trade policy reforms undertaken by a subset of countries that are bound by an environmental agreement (referred to as an environmental union). A perfectly competitive general equilibrium model of world trade is used that includes trade tariffs, environmental taxes and international transfers to address trade and environmental distortions. The first-best optimal trade and environmental policies for the union are derived in the presence and absence of transfers and we find that the transfers internalise the negative externalities (trade and environmental) from the non-union countries. Thereafter, starting from an initial arbitrary tariff and pollution distorted equilibrium, the necessary and sufficient conditions for the existence of strict Pareto-improving reforms to be undertaken by the union are developed. Specific reforms are characterised and applied to analyse the change in welfare of the union and non-union countries. We find that, even in the presence of multiple policy options to target multiple distortions, there exists a negative relationship between the change in welfare of the union and that of the non-union countries and it stems from the terms of trade effect. A 3X3 example is used to elaborate on the specific reforms and the conditions under which the union Pareto improving reforms are welfare reducing for the non-union countries. These conditions depend on the relative magnitudes of the terms of trade effect and impact of emissions leakage on global compensated demand. The example is further used to analyse the impact of the reforms on global pollution and we find that under certain conditions, global pollution may increase, despite union policy reforms targeted at reducing their emissions.

∗University of St Andrews, School of Geography and Sustainable Development
†University of Aberdeen, Business School, Department of Economics, Edward Wright Building, Dunbar Street, Aberdeen AB24 3QY, Scotland, UK contact email: nvlassis@abdn.ac.uk
Introduction

The complex web of interconnections between international trade and the environment and the inherent global nature of their policy consequences have emerged as an important feature of international policy negotiations. This is evidenced by the increased number of trade policy agreements that include a comprehensive section on environmental commitments – as seen in the recently signed Comprehensive Economic and Trade Agreement between the EU and Canada (2017), that has a fully fledged chapter covering a wide array of environmental issues. Countries that agree to an environmental agreement may not have their environmental and/or trade policies at the optimal levels. In order for them to move closer to the optimal taxes and thereby benefit from an improvement in their aggregate welfare, imposing piecemeal multilateral reforms would be the next step forward.

The first purpose of this paper is to explore the conditions for the existence of strict\(^1\) Pareto-improving reforms of trade and environmental policy for the set of countries joined by an environmental agreement (henceforth referred to as an environmental union). To this end, we build upon the model framework outlined in Turunen-Red and Woodland (2004), Kosogiannis and Woodland (2013). Specifically, we extend the work of Turunen-Red & Woodland (1991) that derived the conditions for the existence of reforms of trade policy in a many nation world distorted solely by tariffs to consider both tariff and environmental tax reforms, in the presence of both trade and environmental distortions, for a subset of countries in a many nation world. There are similarities in the conditions characterising the two models that arise from the existence of international lump-sum transfers that internalise the effects from the negative externalities of the non-union countries; important differences, however, arise from the presence of multiple distortions. Apart from obtaining general existence theorems, our research further contributes to this field by considering concrete tariff and environmental reform proposals for a subset of countries forming an environmental union. The rationale for including tariff reforms in an environmental union lies in the fact that the terms of the IEA (international environmental agreement) may dictate initial environmental standards to be adopted by the members which may not be at the optimal levels. In this case, we analyse the conditions under which the union can benefit from a Pareto-improvement in welfare by adopting piecemeal tariff reforms.

The relevant literature surrounding environmental policy reforms can be classified on the basis of: (i) key model assumptions (perfect or imperfect competition), (ii) context (unilateral or fully cooperative) and (iii) implications of the reform (on welfare or global emissions).

A strand of literature focuses on the direction of reform, for small or large economies, using a perfectly competitive setting or under imperfect competition (Lahiri & Symeonidis 2007, Gautier 2013). The papers that use the perfectly competitive setting often consider the context where when

---

\(^1\) The strictness criteria ensures that every country within the union gains from the reform, as only these reforms will get unanimous approval.

Another related body of work explores the conditions for the existence of piecemeal tariff reforms, albeit in the absence of pollution parameters. This includes papers considering unilateral tariff reform by a small open economy (Bruno 1972, Fukushima 1979) and extended to a many household framework (Vanek 1964, Fukushima and Kim 1989, Dievert et al 1991, Turunen-Red and Woodland 1991). In the same context, tariff reform is considered in the presence of household transfers, or commodity taxes (Keen 1989, Dievert et al. 1989) as a redistributive mechanism.

Our paper contributes to the literature by identifying multilateral environmental and trade reforms, that would be strictly welfare improving for a subset of countries (environmental union) and concludes with an analysis of the impact of the same on global emissions.

We also analyse the relationship between the changes in welfare of the union and non-countries and we find that there exists a negative relationship between the same, even in the presence of multiple policy options targeting the various distortions. This confirms the robustness of the result from our previous paper which used one policy variable to target both trade and environmental distortions. This negative relationship is explored further using specific reform proposals and analysing their impact on the welfare of the union and non-union countries using a 3X3 case. We find that in the presence of two policy options to target trade and environmental distortions, if one policy option is set higher (than the shadow prices that account for the distortions), the union can benefit from a reform that reduces the second policy variable. This has important policy implications. National engagement in IEAs is often met with resistance due to the perceived loss in comparative advantage associated with increased production costs due to stricter environmental regulation (Rauscher 1997, Conconi 2003, Copeland and Taylor 2005). Domestic production, which becomes costlier due to increased environmental standards is substituted with imports from environmentally lax countries (emissions leakage effect). Consequently, this implies that the countries which do not sign the IEA can benefit from this emissions leakage effect. Our results suggests an environmental union that sets stringent environmental standards within it, can reduce/eliminate trade tariffs amongst members and still benefit from a welfare improvement. In this case, trade policy can be used as a “carrot”, rather than the stick to get countries to increase their environmental standards. Alternatively, it also implies that countries within a free trade agreement, can 'afford' to set higher environmental standards. Recent empirical work provides evidence in favour

---

2This paper includes the reform implications solely on global emissions and not on welfare.
of this implication, where regional trade agreements with detailed environmental provisions (compared to agreements without such provisions) are associate with reduced levels of carbon dioxide emissions and suspended particulate matter (Baghdadi et al., 2013; Zhou, 2017). A final implication of the above is in support of international policy negotiations that highlight the fact that trade policies should have an environmental component and vice versa. Researchers analysing preferential trade agreements (PTAs) find that in some cases of PTAs, the climate provisions are more specific and enforceable than the Kyoto Protocol and the Paris Agreement (Morin & Jinnah, 2018). Another study analysing free trade agreements in East Asia finds an enhancement in environmental cooperation amongst the participating countries (Yoo & Kim 2016), thereby highlighting the need for trade and environmental policies to go hand-in-hand.

Furthermore, the specific 3X3 case analysis provides evidence that the non-union country may certainly benefit from the emissions leakage effect, but may ultimately face a reduction in welfare if the union’s terms of trade effects dominate the emissions leakage effect. Thus, despite potential emissions leakage effect, the environmental union can still benefit from a strict Pareto-improvement in welfare by imposing environmental tax reforms.

The impact of the reforms undertaken by the environmental union may have an ambiguous effect on the change in global pollution due to the emissions leakage effect. The 3X3 case allows us to find conditions under which pollution may increase or decrease, depending on the magnitudes of emissions leakage effects on compensated demand, welfare and direct effects of policy on production and emissions. The implication of this analysis is that, while the emissions within the environmental union may decrease, the overall global emissions may increase due to the impacts stemming from the emissions leakage effect. Therefore, an IEA on a more “global” scale like that envisioned by the Kyoto protocol would perhaps be more beneficial in reducing global emissions due to the greater inclusivity of countries that reduces the scope of the emissions leakage effect.

The rest of the paper is organised as follows. Section 1 develops a general equilibrium model of international trade that includes pollution. Section 2 derives the optimal (first best) trade and environmental taxes for the environmental union, in the presence and absence of international transfers. Section 3 uses the Motzklin’s theorem of alternatives to derive the existence of and characterise the strict Pareto improving tariff and environmental reforms for the union. Section 4 analyses the relationship between the welfare changes of the union and non-union countries. Thereafter, using a 3X3 case, the impact of specific policy reforms on the welfare of the union are analysed while detailing the conditions for the reforms to be welfare reducing for the non-union country. The section ends with an analysis of the union’s policy reforms on the changes in global pollution. Section 5 concludes.

1 Model Set up

We consider a perfectly competitive general equilibrium model of international trade that in-
cludes pollution. The world economy consists of \( N \) nations that trade in \( Q \) commodities. In each country there is a representative consumer and a private sector that produces \( Q \) goods. The \( Q \)-vector of world prices is denoted by \( p \). The internationally traded goods are subject to a nation specific vector of tariffs denoted by \( t^j \) where the superscript \( j \) denotes the country. Thus, the domestic prices in country \( j \) are given by \( p^j = p + t^j \). The production of each good generates some polluting emissions (e.g. carbon emissions), with the \( Q \)-vector \( z^j \) denoting emissions produced by the \( Q \) commodities in country \( j \). These emissions are subject to a sector specific vector of emissions tax \( s^j \). The production sector in country \( j \) is characterised by a revenue function \( G^j (p^j + t^j, s^j) = \max_{y,z} \left\{ p^j y^j - s^j z^j : (y,z) \in T^j \right\} \) \( j = 1, 2, \ldots, N \) where \( T^j \) is the technology set and \( y^j \) is the net output. The net output vector of goods is given by the gradient \( G^j_p \) with respect to domestic prices \( p^j \), while the corresponding pollution emissions is given by:

\[
z^j = -G^j_s (p^j + t^j, s^j) \quad j = 1, 2, \ldots, N.
\]  

We assume that the quantity of polluting emissions is chosen optimally so as to maximise producers’ profit, thus implying that the production sector is able to control, and if desired, to be able to abate these discharges. The impact of a change in prices (through a change in tariffs) and environmental tax on the production sector’s decision making is given by the second derivatives of the revenue function. The matrices provide information regarding the degree of substitutability or complementarity among traded goods \( (G^j_{pp}) \); between traded goods and polluting emissions \( (G^j_{ps}) \); and among the various pollutants \( (G^j_{ss}) \).

Pollution is assumed to be fully trans-boundary and thus global pollution is given by the sum of all countries’ emissions:

\[
k = \sum_{j=1}^{N} i^j z^j
\]

where \( i \) represents the \( Q \)-vector of 1s.

---


4All vectors are column vectors and a prime indicates the transpose.

5Environmental policy can include emissions taxes and/or emissions quotas. In our analysis, we limit environmental policy to emissions taxes. Economists typically regard a carbon tax as the most efficient way to reduce carbon emissions (Pearce, 1991; Tullock, 1967).

6The revenue function has standard properties of homogeneity, convexity and differentiability. For the properties of the revenue function, refer to Dixit and Norman (1980)

7Henceforth, subscripts denote derivatives or gradients

8The technology to abate the emissions will be described by the technology set \( T^j \)

9\( G^j_{ss} = -\partial z^j / \partial s^j \) gives the impact of a change in the \( n \)th pollutant’s tax on the discharges of the \( n \)th pollutant. Thus, the matrix includes the possibility that policy induced reductions in some polluting discharges may lead to an expansion in the output of other pollutants. \( G^j_{ss} \) and \( G^j_{pp} \) are positive semidefinite.

10The global pollution function can be generalised to \( q^k = f^k (z^1, z^2, \ldots, z^N) \) to allow for global, regional, and localized environmental effects.
The consumption sector in country \( j \) is described using the expenditure function 
\[
E^j (p + t^j, k, u^j) = \min_x \{ p'x^j : U^j (x, k) \geq u^j \} \quad j = 1, 2, ..., N
\]
where \( U^j \) is the utility function and \( x^j \) is the consumption vector. The expenditure function so defined over \( k \) indicates that the minimum cost of achieving a given level of welfare depends not only on the domestic prices but also on the quality of the environment. More specifically, \( E^j_k > 0 \) indicates the marginal damage inflicted by various pollutants on welfare and the gradient \( E^j_p \) gives the vector of compensated demand.\(^{11}\) The matrix \( E^j_{pp} \) gives the consumption substitution effects and is negative semidefinite. The sensitivity of (compensated) consumption demand to polluting emissions is given by \( E^j_{pk} \).

For the purpose of convenience, a maximal net revenue function is defined as the difference between national revenues and expenditures:
\[
S^j (p + t^j, s^j, k, u^j) = G^j (p + t^j, s^j) - E^j (p + t^j, k, u^j) \quad j = 1, 2, ..., N
\] \(^{(2)}\)

The maximal net revenue function has the convenient property that national (compensated) net exports can be obtained as the partial derivative \( S^j_p \) with respect to domestic prices.\(^{12}\) The output of pollutants can then be written as \( z^j = -G^j_s = -S^j_k \). The net substitution matrix is given by \( S^j_{pp} = G^j_{pp} - E^j_{pp} \) and yields the response of net (compensated) exports to changes in domestic relative prices.\(^{13}\) The matrix \( S^j_{ps} \) gives the effect of a change in environmental taxes on net exports (through their effect on production), while \( S^j_{sp} \) gives the impact of change in prices on emissions.\(^{14}\)

The first traded commodity is taken as the numeraire, with respect to which all other relative prices are measured.\(^{15}\) Now, the vector of world prices is represented as \( p' = (1, w') \), where \( w \) denotes the prices of the remaining \( Q - 1 \) non-numeraire goods. We assume that countries 1 to \( M \) form an environmental union denoted by the superscript \( u \in [1, M] \) and all the non-union countries are represented by the superscript \( f \in [M + 1, N] \). The equilibrium conditions for the world economy are expressed as follows:
\[
\sum_{j=1}^{N} S^j_{wu} (p + t^j, s^j, k, u^j) = 0_{N-1} \quad \text{(3)}
\]
\[
\sum_{u=1}^{M} p'u'S^j_w (p + t^u, s^u, k, u^u) = \sum_{u=1}^{M} b^u \quad u = 1, 2, ..., M \quad \text{(4)}
\]

\(^{11}\) The expenditure function is concave and linearly homogenous in prices, increasing in utility, and assumed to be twice continuously differentiable.

\(^{12}\) The function \( S^j (\cdot) \) inherits its curvature properties from the underlying revenue and expenditure functions.

\(^{13}\) Matrix \( S^j_{pp} \) is positive semidefinite.

\(^{14}\) \( S^j_{pw} \) is the marginal net expenditure arising from an additional unit of utility (inverse of the marginal utility of income), while \( S^j_{ps} \) is the effect of the additional utility on compensated imports (through demand). Thus \( S^j_{pw}/S^j_{ps} \) is the income effect for the consumer in country \( j \).

\(^{15}\) This numeraire is also assumed to be untaxed by any nation.
\[ p' S_p (p + t^f, s^f, k, u^f) = b^f, \quad f = (M + 1), ...N \quad (5) \]

\[ k = \sum_{j=1}^{N} i^j z^j \quad (6) \]

\[ z^j = -S_k (p + t^j, s^j, k, u^j), \quad j = 1, 2, ..., N \quad (7) \]

\[ \sum_{j=1}^{N} b^j = 0 \quad (8) \]

Equation 3 gives the international market clearing condition for the non-numeraire commodities.\textsuperscript{16}

Equation 4 gives the budget constraint for the union. In this case, countries 1 to M (the environmental union) maximise their joint welfare subject to their budget constraint, where \( b^j \) is the national trade balance or the international transfer from country \( j \) to the rest of the world. Equation 5 gives the budget constraint for the non-union country. In both cases, it is assumed that the tariff and tax revenue is returned to the consumers in a lump-sum manner. The case in which \( b^j = 0 \) describes the situation where there are no international transfers. Equation 8 denotes that the sum of all international transfers should equal zero. Equation 7 defines the national pollution emissions, while equation 6 specifies the case of fully transboundary global pollution. Thus, the above system of equations specifies three policy instruments – namely, trade tariffs, environmental taxes and international transfers – which are exogenously given.

We focus on differential tariff and tax reform given by the vectors \( dt^j \) and \( ds^j \) respectively, accompanied by a differential change in international transfers \( db^j \), which will cause adjustments in the world price vector and the utility levels of all consumers to establish a competitive equilibrium. The changes in these policy instruments and other endogenous variables are obtained by computing the differential comparative static system for the model. Fully differentiating the system of equations 3 to 8 at the initial equilibrium yields:

\[ A du + B dw + C dt + D ds + E dk + F db = 0 \quad (9) \]

Given that the purpose of this paper is to identify Pareto improving union reforms and their impact on non-union members’ welfare, we assume that all non-union countries are policy passive and thus set \( dt^f = 0 \) and \( ds^f = 0 \). However, there still exist international transfers among and between union countries and the rest of the world.\textsuperscript{17}

\textsuperscript{16}The market clearing condition for the numeraire has been dropped in accordance with Walras’ Law.

\textsuperscript{17}This is a realistic assumption as evidenced by the transfers from developed to developing countries as foreign aid for various reasons (Morgenthau 1962); for humanitarian relief purposes (Stromberg 2007); or in the form of technology.

7
2 Pareto-efficient Climate and Trade Policies

This section lays out the optimal environmental and trade policies for the union under two scenarios: in the presence of international lump-sum transfers and in their absence. In order to arrive at the optimal policies, we specify the following pollution augmented world net substitution matrix:

\[
R_{pp} = \sum_{j=1}^{N} R^j_{pp} = \begin{bmatrix} R_{p1} & R_{pw} \\ R_{w1} & R_{ww} \end{bmatrix} = \sum_{j=1}^{N} S^j_{pp} - \sum_{j=1}^{N} \sum_{k=1}^{N} S^j_{pk} S^k_{sp} \tag{10}
\]

Matrix \(R_{pp}\) yields the responses in the world net exports to changes in the terms of trade, when we account for effects that arise from consumer demand as the environmental quality changes.\(^{18}\) The environmental quality effects on consumption are given by \(\sum_{j=1}^{N} \sum_{k=1}^{N} S^j_{pk} S^k_{sp}\). This term describes the changes in relative prices, which then alter national production patterns and pollution output (given by \(S^j_{sp}\)), leading to changes in global environmental quality that further yield corresponding adjustments in consumption \(S^j_{pk}\). These indirect effects on consumption are summed across all countries and are added to the usual consumption substitution term \(E^j_{pp}\) which is included in \(S^j_{pp}\). We assume that the \((Q-1) \times (Q-1)\) pollution augmented world net substitution matrix \(R_{ww}\) for non-numeraire commodities is invertible. This implies that there is a sufficient degree of responsiveness in consumption and production to changes in relative prices, so as to ensure that the (compensated) world net exports are smoothly adjusting functions of \(w\).

We define two types of shadow prices.\(^{19}\) One may be interpreted as the shadow world price vector for traded commodities as:

\[\hat{p}' = p' - \left(0, p'R_{pw}R_{ww}^{-1}\right)\]

where \(\hat{p}'\) differs from world market prices as a result of market distortions (trade and environmental) as reflected by the correction term \(p'R_{pw}\). This term reduces to zero, thus making \(\hat{p}' = p'\), if no distortions exist, i.e. if: (a) there is free trade \(t^j = 0, j = 1, ..., N\), and (b) environmental quality does not directly affect compensated demand \(E^j_{pk} = 0, j = 1, ..., N\). If either of these two conditions

\(^{18}\)Where

\[R_{ww} = \sum_{j=1}^{N} (S^j_{ww}) - \sum_{j=1}^{N} (S^j_{wk}) \sum_{j=1}^{N} S^j_{sw}\]

\[R_{pw} = \sum_{j=1}^{N} S^j_{pw} - \sum_{j=1}^{N} (S^j_{pk}) \sum_{j=1}^{N} S^j_{sw}\]

\(^{19}\)Ref Turunen-Red and Woodland, 2004; Koussogiannis & Woodland, 2013
are violated, then the correction term does not collapse to zero and world market prices can no longer accurately reflect the welfare value of traded goods. Trade distortions are non-zero whenever the domestic relative prices of private goods are not the same in all countries. The shadow price takes into account the fact that world prices may be affected by any exogenous project (e.g. a public project like intra-country rail lines, highways) that alters pollution-augmented world excess supplies \( R_{ww} \), thereby affecting the world tariff revenue \( p'R_{pw} \) in turn. Alternatively, \( p' \) differs from \( p \) by a weighted average of tariff rates with the weights reflecting the relative importance of each country in the pollution augmented world net substitution matrix, \( R_{pp} \). The shadow tariff \( \hat{t} = \hat{p} - p \) captures the totality of the distortions from the world point of view.

Similarly, the second shadow price can be interpreted as the shadow price vector for pollution emissions:

\[
\hat{s}' = -\hat{p}' \sum_{j=1}^{N} \left( S_{pk}^j \right)
\]

As world shadow prices are the appropriate prices at which public policy projects should be evaluated, pollution emissions in public policy projects should also be evaluated in a similar vein. This leads to the definition of \( \hat{s}' \) which gives the world shadow prices augmented by the impact of emissions on preferences. Environmental distortions are non-zero whenever taxes (or other forms of carbon control) on polluting discharges in any country do not reflect the domestic and international consequences of these emissions properly. Thus \( \hat{s}' \) is the appropriate pollution price vector to be used to evaluate emissions in public policy projects. This term collapses to zero if emissions do not affect consumer (compensated) demand \( E_{pk}^j = 0, j = 1, ..., N \). This vector is the same for all countries given the global nature of pollution. The shadow price for emissions can also be written as: \( \hat{s}' = \sum_{j=1}^{N} E_{pk}^j \), which states that the shadow price of an extra unit of emission should equal to the marginal global damage that the extra unit of emissions causes through climate change.

Thus, the world shadow price vector \( \left( \hat{p}' \right) \) and the world shadow emissions tax vector \( \left( \hat{s}' \right) \) encompass both the general equilibrium market effects and the climate change effects. While market prices and environmental taxes are relevant for private production and consumption, policy makers need to take into account the trade and pollution externalities and hence must use the shadow prices to undertake policy decisions.

Solving equation 9 using Motzkin’s Theorem of alternatives (detailed in section 3), we arrive at the optimal policies described by the following proposition:

**Proposition 1:** In the presence of international transfers, Pareto efficiency requires that in every country within the union:
a) Environmental taxes are set at \( s^{u-opt} = -\hat{p}' \sum_{j=1}^{N} (S_{pk}^j) = \hat{s}' \), implying that they are uniform across sectors within a country and also uniform across countries;

b) Tariff vectors are equal and set at \( t^{u-opt} = -0, p'R_{pw}R_{ww}^{-1} = \hat{t}' \), thus making the domestic price vectors equal across the union countries.

Thus, due to the existence of transfers between union and non-union countries, the optimal union policies are equal to the shadow prices and tariffs. This is because of the re-distributive effects of the transfers that ensure the union policies account not only for their impact on union countries but also on non-union countries via the trade and environmental distortions. The presence of international transfers leads to the inclusion of the budget constraints of the non-participating countries, which means that the solution to the system of equations corresponds to the fully cooperative policy. Note that the optimal emissions tax derived above is consistent with a fully cooperative solution obtained when we include only one policy variable to deal with both environmental and trade distortions. The results are also consistent with the literature – see, e.g., Keen & Kotsogiannis (2014), Vlassis (2013), Kotsogiannis & Woodland (2013) – even though the model is based on different mechanisms of climate change influences.

Proposition 1 of Keen & Kotsogiannis (2014) uses marginal welfare weights for each of the countries and derives the optimal carbon tax to equate the sum of the marginal environmental damages (from pollution) faced by all the countries. The inclusion of marginal welfare weights allows for the level of optimal tax to differ across countries. In our case, this translates in all the countries being assigned a marginal welfare weight equal to 1, and arriving at the same result. The implication of this optimal tax is that the marginal damage from emissions is the same, irrespective of the sector that they originate in, and that each union country should apply the same carbon tax to all activities within each country. The authors find that the optimal tariff vectors are collinear, implying that global production will be efficient. Our case of optimal tariffs are consistent in the sense that all countries set the same tariffs, which are equal to the shadow tariffs and hence imply an efficient global production.

Proposition 2: In the absence of transfers between union and non-union countries, Pareto efficiency requires that every country within the union sets:

a) Environmental taxes as \( s^{u-opt} = p' \sum_{u=1}^{M} E_{pk}^u - (p'R_{pw}^U + S_{w}^U) R_{ww}^{-1} \sum_{j=M+1}^{N} E_{pk}^j \)

b) Tariff vectors as \( t^{u-opt} = - (p'R_{pw}^U + S_{w}^U) R_{ww}^{-1} \), thus making the domestic price vectors equal across the union countries.\(^\text{21}\)

\(^{20}\)The homogeneity condition of the maximal revenue function implies \( p'S_{pk}^j \equiv S_{k}^j \). This leads to \( s^{u-opt} = \sum_{j=1}^{N} S_{pk}^j \)

\(^{21}\)In the above:

\[
R_{pw}^U = \sum_{u=1}^{M} S_{pw}^u - \sum_{u=1}^{M} (S_{pk}^u) \sum_{j=1}^{N} S_{sw}^j
\]
In the absence of international transfers to non-union countries, the union members set their Pareto-optimal environmental tax to account for the impact of pollution on the union’s compensated demand \( p^u \sum_{u=1}^{M} E^u_{pk} \) and an adjustment factor that discounts the impact on compensated demand of the non-union countries \( - (p^U R^U_{pw} + S^U_w) R^{-1}_{ww} \sum_{f=M+1}^{N} E^f_{pk} \). The optimal tax can also be represented as:

\[
S_{u-opt} = \sum_{u=1}^{M} E^u_k + t_{u-opt} \sum_{f=M+1}^{N} E^f_{pk}. 
\]

This representation states that the optimal union policy reflects only its own (union’s cumulative) marginal damage and a tariff term (akin to a border tax adjustment) to account for the impact of a change in the compensated demand from the non-union countries.

The optimal union tariff reflects two effects: the distributional effects of the terms of trade associated with changing tariffs within the union \( - S^{U}_w R^{-1}_{ww} \) and the pollution augmented change in the union’s net exports from changing world prices \( - p^U R^U_{pw} R^{-1}_{ww} \). Thus, the tariff vectors are set equal within the union, which makes the union’s domestic price vectors, hence the environmental tax vectors, equal across the union countries. The key difference between this vector of optimal tariffs and that from Proposition 1 is that here the tariffs account for union-specific substitution matrix and terms of trade as opposed to global distortions.

The difference in the optimal policies in both the Propositions is that the transfers in the Proposition 1 corrected for the negative externality from the trade and environmental distortions of the non-union countries. In the absence of transfers, the union’s optimal policies have to now specifically account for the same which leads to the additional terms.

### 3 Existence of Strict Pareto Improving Reforms

The following section develops the necessary and sufficient conditions for the existence of strict Pareto-improving reforms of union tariffs and environmental taxes. This section builds upon the work of Turunen-Red and Woodland (1991) who obtain conditions for strictly Pareto improving multilateral reforms of tariffs. Our work differs by including pollution and pollution distortion as well as considering reforms for a subset of countries (the environmental union). The policy reform is defined to be a differential change in the vector of policy variables of the union \( (ds^u \text{and/or } dt^u) \). Assuming that the union countries agree on a perturbation of the initial international transfers \( db^u \), as part of the policy reform, the section determines the necessary and sufficient conditions under which there exists a differential change \( (dt^u, ds^u, db^u) \) such that the welfare of the union is improved. Even if the

---

\(^{22}\)The optimal policies outlined in Proposition 2 are qualitatively consistent with the non-cooperative optimal policies of a single country in Keen & Kotsogiannis (2014). The reason for the consistency is that in the absence of transfers, maximisation of the joint union welfare (leading to the union members setting the same tariff and tax vectors) implies that the union can be considered as one unit that sets its optimal policies in a non-cooperative manner with respect to the rest of the world.

11
Policy reform is undertaken unilaterally by a single union member, it is done so as to improve the union’s aggregate welfare. Formally, the problem is to identify the circumstances where there exists a \((du, dw, dt, ds, dk, db)\) such that 9 holds and \(du^u \gg 0\) for all \(u \in \{1, M\}\). This is accomplished using Motzkin’s Theorem of the Alternative\(^{23}\), which gives the equivalent condition that there is no vector \(y \in R^{(Q-1)+N+1+Q}\) such that
\[
y' [B, C, D, E, F] = 0 \quad y'A < 0
\]

**Proposition 3:** If the matrix \(R_{pp}\) for non-numeraire goods is of full rank, then a strict Pareto-improving union tariff and/or environmental tax reform exist if, and only if, there is no scalar \(\mu \in R\) that satisfies the following conditions:

\[
\mu [\beta^1, ..., \beta^M] < 0 \tag{11}
\]

\[
\mu \left( \hat{p}' S_{pu} + \hat{s}' S_{su} \right) = 0 \quad u = 1, ..., M \tag{12}
\]

\[
\mu \left( \hat{p}' S_{pu} + \hat{s}' S_{ss} \right) = 0 \quad u = 1, ..., M \tag{13}
\]

where \(\beta^u = \hat{p}' S_{pu}\)

The solution to the system of equations 11, 12 and 13 depends on the nature of substitution possibilities in both production and consumption \((S_{pu})\), the response of consumer demand to income changes \((S_{pu})\) and to changes in environmental quality \((E_{pu})\), the impact of prices and environmental taxes on emissions \((S_{su}^u\) and \(S_{ss}^u\)), the shadow price vector \((\hat{p})\) and implicitly on tariff structures. If the above equations have a solution, then Proposition 3 indicates that a strict Pareto-improving tariff and tax reform does not exist. Conversely, if there is no solution, then there exists a tariff and/or tax reform accompanied by a change in international transfers such that the utility levels of all consumers within the union increase, that is, \(du^u \gg 0\).

Proposition 1 can be reduced further by understanding condition 11. This condition fixes the direction of the welfare improvement by ensuring that each union country will gain from an income transfer (from other union countries). The welfare weights \((\beta^u)\) are price weighted sums of the income effects in consumption \((-S_{pu}^u = E_{pu})\); then, condition 11 will hold if, for example, all goods are normal in consumption and \(\hat{p} \gg 0_N\). In the literature on policy reform for large open economies, \(\hat{p}' E_{pu}^u > 0\) is referred to as the generalized Hatta normality condition. This condition states that the effect of an increase in income in each union country (estimated by a utility gain) increases the value of the country’s net imports, the evaluation of which, is done at world shadow prices \((\hat{p})\).\(^{24}\) The literature

\(^{23}\)The theorem is stated in Mangasarian 1969, p.34

has also shown that as long as at least one country satisfies the generalised Hatta normality condition, income transfers alone can generate a Pareto improvement in welfare.\textsuperscript{25} Thus, if all nations except one satisfy the condition, then a strict Pareto improvement in welfare is possible without changing any tariffs. In order to focus unambiguously on the welfare gains arising from tariff and environmental tax reforms, one can assume that all the union countries satisfy the generalised Hatta normality condition. However, this is not a necessary assumption, as long as at least one union country satisfies the generalised Hatta normality condition. This assumption implies that proposition 3 reduces to:

**Corollary 3.1:** If there is at least one union country satisfying the generalised Hatta normality condition and $R_{pp}$ for non-numerairre good’s is of full rank, then there exists a strict Pareto-improving differential tariff and/or environmental tax reform (accompanied by suitable income transfers) if, and only if, there is at least one union country for which:

\begin{equation}
\hat{p}'S_{pp} + \hat{s}'S_{sp} \neq 0
\end{equation}

\begin{equation}
\hat{p}'S_{ps} + \hat{s}'S_{ss} \neq 0
\end{equation}

Conditions 14 and 15 are necessary and sufficient conditions for the existence of strict Pareto improving union policy reforms. If there exists no trade or environmental distortions, $\hat{p}'$ collapses to world prices $p'$ and individual country prices also become equal to the world prices thus making condition 14 violate the homogeneity conditions of the maximal net revenue function.\textsuperscript{26} Thus in the presence of tariff and environmental distortions, conditions 14 and 15 are sufficient to ensure the existence of welfare improving reforms for the union. Condition 14 provides the base for the existence of a strictly Pareto improving tariff reform. The condition represents the impact of a tariff reform on the value of the country’s net exports of goods and on its emissions weighted by the world shadow prices of goods and emissions respectively. Similarly, condition 15 gives the basis for the existence of a strictly Pareto improving environmental tax reform by a union country. The condition represents the impact of an environmental policy reform on the value of the net imports and emissions of the country evaluated at the world shadow goods and emissions price vector.

Proposition 3 and corollary 3.1 identify conditions under which strictly Pareto-improving policy reforms for the union exist. The next step is to specify some of these policy reforms. The general

\textsuperscript{25}In the case of only tariffs and transfers, refer to Turunen-Red and Woodland, 1988. An analogous argument is made in the case of transfers and tariffs in the presence of environmental taxes in Turunen-Red and Woodland, 2004.

\textsuperscript{26}The homogeneity can be expressed as

\[ p^{ur}S_{pp} + s^{ur}S_{sp} = 0 \]

and

\[ p^{ur}S_{ps} + s^{ur}S_{ss} = 0 \]

Thus, in case of no trade or environmental distortions, $s^{u} = 0$ and the homogeneity condition gets reduced to $p^{ur}S_{pp} = 0$
type of reforms considered are a change in union environmental taxes (and/or tariffs) along a vector \( \theta \) (vector \( \alpha \)) as defined to be a reform of the union’s tax (tariff) vector such that \( ds = \theta d\theta \) and \( dt = \alpha d\alpha \), where \( \theta \) and \( \alpha \) are vectors indicating the hyperplane of feasible changes in \( s \) and \( t \), and \( d\theta \neq 0 \), \( d\alpha \neq 0 \) are the distance of movement along \( \theta \) and \( \alpha \) respectively. The following Proposition 4 and Corollary 4.1 give the necessary and sufficient conditions under which the above mentioned reform specification by the union are strictly Pareto improving. These do not provide a direct guidance as to the directions of the reform; they depend on the nature of the pollution augmented trade matrix. The reform specification allows for both an increase as well as a decrease in tax and/or tariff levels in order to achieve the Pareto-improvement outcome contained in the following propositions.

**Proposition 4:** If the matrix \( R_{pp} \) for non-numeraire goods is of full rank, then a change in tariffs along \( \alpha \) (i.e. a change of tariffs of the form \( dt = \alpha d\alpha \), \( d\alpha \neq 0 \)) and/or a change in environmental taxes along \( \theta \) (i.e. a change of the form \( ds = \theta d\theta \), \( d\theta \neq 0 \)) is strictly Pareto improving if and only if there is no scalar \( \mu \in \mathbb{R} \) such that

\[
\mu [\beta^1, ..., \beta^M] < 0
\]

\[
\mu \gamma = 0; \quad \mu \eta = 0
\]  

(16)

where \( \gamma = \sum_{u=1}^{M} \left( \hat{p}' S_{uu}^p \alpha^u + \hat{s}' S_{up}^u \alpha^u \right) \) and \( \eta = \sum_{u=1}^{M} \left( \hat{p}' S_{sp}^u \theta^u + \hat{s}' S_{ss}^u \theta^u \right) \)

Proposition 4 shows the ability of a union tariff and/or tax reform, accompanied by suitable income transfers between the union members, to yield a strict Pareto improvement in union welfare. This is dependent on income effects, substitution effects and the extent of the initial tariff and environmental distortion. The income effects are captured by \( \beta^u \) while the substitution effects are captured by the national matrices \( S_{pp}^u, S_{ps}^u, S_{sp}^u \) and \( S_{ss}^u \). The world shadow price vector of traded goods \( \left( \hat{p}' \right) \) and polluting emissions \( \left( \hat{s}' \right) \) reflect the tariff and environmental distortions.

**Corollary 4.1:** If the matrix \( R_{pp} \) for non-numeraire goods is of full rank,

- Then, a change in tariffs along \( \alpha \) will be strictly Pareto-improving for the union if \( \gamma \neq 0 \)
- And a change in environmental taxes along \( \theta \) will be strictly Pareto-improving for the union if \( \eta \neq 0 \)

The Corollary focuses attention on the terms \( \gamma \) and \( \eta \) and the sufficiency condition to ensure strict Pareto improvement along union tariff reform \( \alpha^u \) and/or along the union environmental reform \( \theta^u \). \( \gamma \)
represents the impact of a union tariff reform on the value of the union’s net exports of goods and on the union’s emissions, weighted by world shadow prices of goods and emissions respectively. Similarly, \( \eta \) represents the impact of a union environmental reform on the union’s net good exports and union emissions evaluated at their respective world shadow prices. In the following section, specific policy reforms are considered. 27

Characterisation of Policy Reforms by the Union

This section lays out specific union policy reforms following from Corollary 4.1 that would lead to strict Pareto-improvements in the welfare of the union. The strategy is to show that \( \eta \neq 0 \) for an environmental policy reform and \( \gamma \neq 0 \) for a trade policy reform and use Corollary 4.1 directly to demonstrate the existence of strict Pareto improvements in union welfare. The following section provides multilateral reforms of both trade and environmental policies under the presence of lump-sum income transfers. The union can choose to implement both policy reforms at the same time or one of them at a time, in order to ensure strict Pareto improvement in welfare. Research by Turunen-Red and Woodland (2004), show that the welfare improvements caused by environmental reforms accompanied by income transfers can be replicated using the environmental reforms in conjunction with suitable tariff reforms. Thus, in our case, the union can choose to undertake both policy reforms simultaneously in the absence of international transfers.

Environmental Policy reforms

The following specific reform proposals are qualitatively consistent with those outlined in Turunen-Red and Woodland (2004) and Kotsogiannis and Woodland (2013).

**Proposition 5:** If the matrix \( R_{pp} \) for non-numeraire goods is of full rank and assuming further that

\[
\sum_{u=1}^{M} \hat{p}^u S_{vp} \hat{s} > 0
\]  

(17)

then a multilateral union reform of environmental taxes along the vector \( \theta^u \)

\[
\theta^u = \delta \hat{s}, \quad \delta > 0
\]

---

27The above propositions detailing the existence of Pareto improving reforms can be compared to the multilateral tariff reforms of Turunen-Red and Woodland (1991). The authors consider a many-nation world with only trade distortions and tariffs to deal with the same. Their conditions of the existence of multilateral and unilateral tariff reforms are qualitatively consistent with our case that deals with both trade and environmental policy reforms.
is strictly Pareto-improving for the union.

where $\delta$ is a scalar. The above reform is of the type $ds^u = \delta \hat{s} \theta$. This implies a change in union members' environmental taxes proportional to the global marginal damage of pollutants. Thus, the reform might involve a reduction in existing environmental taxes for some members and an increase for others. Assumption 17 states that the reallocation of union’s output of traded goods (caused by the environmental reform and measured by the vectors $\hat{p}' S_{ps}^u$) is positively correlated with the marginal damage of pollutants (represented by $\hat{s}$).

**Proposition 6:** If the matrix $R_{pp}$ for non-numeraire goods is of full rank and assumption 17 holds, then a multilateral union reform of environmental taxes along the vector $\theta^u$

$$\theta^u = \delta \left(s^{u-opt} - s^u\right), \quad \delta > 0$$

is strictly Pareto-improving for the union.

This reform moves the environmental taxes of the union countries towards a common target (optimal union tax), i.e., it reduces any initial differences that may exist in the environmental taxes across the members. Thus, this may imply a reduction in existing environmental taxes for some countries and an increase for others.

**Trade policy reforms**

The structure of the specific trade policy reforms detailed below are consistent with those outlined in the literature on tariff reforms (not including the presence of pollution parameters) (see, e.g., Diewert et al. 1989, Turunen-Red and Woodland 1991).

**Proposition 7:** If the matrix $R_{pp}$ for non-numeraire goods is of full rank and assuming further that

$$\sum_{u=1}^{M} s^u S_{sp}^u \hat{p} \neq 0$$

then, a multilateral union reform of trade tariffs along the vector $\alpha^u$

$$\alpha^u = \epsilon \hat{p}, \quad \epsilon > 0$$

is strictly Pareto-improving for the union. Where $\epsilon$ is a positive scalar. The reform in 19 suggests that the union countries change their tariffs proportional to the world price vector. This may lead to tariff increases or decreases by union countries. The assumption 18 implies that the re-allocation of union’s output of emissions (caused by the indirect effect of the tariff reform on emissions via changes in production levels, as measured by $s^u S_{sp}^u$) is correlated with the shadow prices for traded goods ($\hat{p}$).
If this is a positive correlation, i.e. if $\sum_{u=1}^{M} s^u S_{sp}^u \hat{P} > 0$ then $d\alpha > 0$, indicating that the union tariffs are increased proportionately with the world shadow prices. Instead, if the correlation is negative, and the impact of pollution on compensated demand is greater than the effect of the change in prices on compensated net exports of the union $\left[ \sum_{u=1}^{M} R_{pp}^u < 0 \right]$, then $d\alpha < 0$ and union tariffs would be decreased proportionately with the world shadow prices.\(^{28,29}\)

**Proposition 8:** If the matrix $R_{pp}$ for non-numerarie goods is of full rank and condition 18 holds then a multilateral union reform of trade tariffs along the vector $\alpha^u$

$$\alpha^u = \epsilon \left( t^u - opt - t^u \right), \quad \epsilon > 0$$

is strictly Pareto-improving for the union.

This reform involves a proportional shift towards optimal union tariffs. In the case where there are international transfers (refer to section 2.2), the reform obtained in Proposition 8 indicates a proportional reduction in trade distortions. In either case (presence or absence of international lump-sum transfers), this reform specification moves the union tariffs towards a common target (shadow tariffs or optimal union tariff).

### 4 Welfare of the Union

While the earlier sections used Motzkin’s Therem of Alternatives to derive optimal policies and provide the conditions necessary for the existence of strict Pareto-improving reforms for the union, this section delves into the changes in welfare of the union as well as of the non-union countries. Our earlier paper that used only one policy instrument to target multiple distortions, found the existence of a negative relationship between the welfare changes of the union and non-union countries. This paper aims to verify the robustness of the result in the case where we have several policy instruments to target the corresponding distortions.\(\ast\) We find that this is indeed the case. Thereafter, we explore this negative relationship by characterising specific union reforms that are welfare improving for the union and welfare reducing for the non-union countries.

Fully differentiating the equilibrium conditions and substituting for the value of $dw$ and $dk$ in the differentiated budget constraint, we obtain:

\(^{28}\)This type of a reform was introduced in Turunen-Red & Woodland 1991 for the case of unilateral tariff reform.\(^ {29}\)

$R_{pp}^u = S_{pp}^u - S_{pk}^u S_{sp}^u$
\[ \sum_{u=1}^{M} \left[ p_u^{\hat{U}_t} - X^{U_t} \right] E_{pu}^{u} du^u = \sum_{u=1}^{M} \left\{ \left[ p_u^{\hat{U}_t} - X^{U_t} \right] S_{pp}^{u} + \left[ s_u^{\hat{U}_t} + X^{U_t} + p' \left( \sum_{f=M+1}^{N} S_{pk}^{u} \right) \right] S_{sp}^{u} \right\} dt^u \\
+ \sum_{f=M+1}^{N} \left\{ \left[ p_f^{\hat{U}_t} - X^{U_t} \right] S_{pf}^{f} + \left[ s_f^{\hat{U}_t} + X^{U_t} + p' \left( \sum_{u=1}^{M} S_{pk}^{u} \right) \right] S_{sf}^{f} \right\} ds^f \\
+ \sum_{f=M+1}^{N} \left\{ \left[ t_f^{\hat{U}_t} - X^{U_t} \right] S_{pf}^{f} + \left[ s_f^{\hat{U}_t} + X^{U_t} + p' \left( \sum_{u=1}^{M} S_{pk}^{u} \right) \right] S_{sf}^{f} \right\} ds^f \\
- \sum_{f=M+1}^{N} \left[ t_f^{\hat{U}_t} - X^{U_t} \right] E_{pf}^{f} du^f \\
- \sum_{u=1}^{M} db^u \] (20)

The left hand side of equation 20 gives the change in the welfare of the union \( \left( \sum_{u=1}^{M} \left[ p_u^{\hat{U}_t} - X^{U_t} \right] E_{pu}^{u} du^u \right) \) as a function of the change in policy variables on the right hand side, namely: union trade tariffs \( (dt^u) \), union environmental taxes \( (ds^u) \), union transfers to the rest of the world \( (db^u) \), and the change in policy variables of the non-union countries \( (dt^f, ds^f) \). The first two terms on the right hand side give the impact of a change in prices (brought about by a change in tariffs) on net exports and on emissions. The next two lines provide the impact of a change in environmental policy on production allocation and emissions. The term \( - \sum_{f=M+1}^{N} \left[ t_f^{\hat{U}_t} - X^{U_t} \right] E_{pf}^{f} du^f \) confirms the negative relationship between changes in the welfare of the union and that of the non-union, even in the presence of multiple policy variables targeting multiple distortions.

In the above equation, \( p_u^{\hat{U}_t} = p' - (0, p') \left( \sum_{u=1}^{M} R_{pu}^{u} \right) R_{w}^{-1} \) is the union shadow price of goods that considers the impact of a change in world prices on the pollution augmented net exports of solely the union countries. Consequently, the shadow tariff considered solely by the union nations is \( t_u^{\hat{U}_t} = - (0, p') \left( \sum_{u=1}^{M} R_{pu}^{u} \right) R_{w}^{-1} \), while the shadow price for emissions that takes into account only the union’s trade distortions is given by \( s_u^{\hat{U}_t} = - p_u^{\hat{U}_t} \left( \sum_{j=1}^{N} S_{pk}^{j} \right) \). The net exports of the union valued at world prices is represented by \( X^{U_t} = (0, 1) \left( \sum_{u=1}^{M} S_{wu}^{u} \right) R_{w}^{-1} \) and the pollution augmented union exports is
given by \( X^{Uf} = \sum_{u=1}^{M} X^{u} \left( \sum_{j=1}^{N} S_{pk}^{j} \right) \).

In a similar vein, the change in welfare of the non-union country is given by:

\[
\left( p^{j} - X^{f} \right) E_{pu}^{f} du^{u} = + \sum_{l=1, l \neq f}^{N} \left[ \left( t^{j} - X^{f} \right) S_{pp}^{l} + \left( s^{j} + \hat{X}^{f} + p' \sum_{l=1, l \neq f}^{N} S_{pk}^{l} \right) S_{sp}^{l} \right] dt^{l}
\]

\[
+ \sum_{l=1, l \neq f}^{N} \left[ \left( t^{j} - X^{f} \right) S_{ps}^{l} + \left( s^{j} + \hat{X}^{f} + p' \sum_{l=1, l \neq f}^{N} S_{pk}^{l} \right) S_{sp}^{l} \right] ds^{l}
\]

\[
- \sum_{l=1, l \neq f}^{N} \left( t^{j} - X^{f} \right) E_{pu}^{f} du^{u}
\]

The change in welfare of country \( f \) is affected by the change in its domestic tariff \( (dt^{f}) \), environmental tax \( (ds^{f}) \), transfers \( (db^{f}) \) and the changes in policies of the rest of the world \( (dt^{l}, ds^{l}) \). In this equation, the \( p^{j}, s^{j}, X^{f}, \hat{X}^{f} \) are defined analogously to the union case, where the variables include only the impact on net exports of the country \( f \). Rearranging the terms to get the international transfers \( db^{f} \) from equation 21, using the international trade balance relationship ?? and substituting for \( \sum_{u=1}^{M} db^{u} \) in 20, we can express equation 20 in a simplified manner to get:

\[
\sum_{u=1}^{M} \hat{p}^{s} E_{pu}^{u} du^{u} = + \sum_{f=M+1}^{N} \left( \hat{p}^{s} S_{pp}^{f} + \hat{s}^{s} S_{sp}^{f} \right) dt^{f} + \sum_{f=M+1}^{N} \left( \hat{p}^{s} S_{ps}^{f} + \hat{s}^{s} S_{sp}^{f} \right) ds^{f}
\]

This equation represents the change in welfare of the union as a function of the change in union and non-union policy variables. The left hand side gives the change in welfare of the union and is \( \left( \sum_{u=1}^{M} \hat{p}^{s} E_{pu}^{u} du^{u} \right) > 0 \) due to the generalised Hatta normality condition discussed in section 3. On
the right hand side, \( \sum_{u=1}^{M} (\hat{p}' S_{pu} + \hat{s}' S_{sp}) dt^u \) gives the direct impact of a change in union tariffs on net compensated union exports and the indirect impact on union emissions. \( \sum_{u=1}^{M} (\hat{p}' S_{pu} + \hat{s}' S_{su}) ds^u \) gives the indirect impact of a change in union’s environmental taxes on its production allocation and the direct impact on the union’s emissions. The second line of the equation provides a similar interpretation but with non-union countries’ policies. The last term highlights the negative relationship between the change in welfare of the union countries and that of the non union countries. This negative relationship stems from the trade balance equation 8 and implies that a Pareto-improving reform of tariffs and/or environmental taxes by the union can be welfare reducing for the non-union countries. Thus, even in the presence of multiple policy variables targeting multiple distortions, there exists a negative relationship between the welfare changes of the union and non-union countries.

In the case in which the non-union countries are policy passive (thus \( dt^f = 0, ds^f = 0 \)), the change in union welfare is simply a function of its own policy variables and the change in welfare of the non-union countries and is given by:

\[
\sum_{u=1}^{M} \hat{p}' E_{pu} du^u = \sum_{u=1}^{M} (\hat{p}' S_{pu} + \hat{s}' S_{sp}) dt^u + \sum_{u=1}^{M} (\hat{p}' S_{pu} + \hat{s}' S_{su}) ds^u - \sum_{f=M+1}^{N} \hat{p}' E_{pu} df^f
\]

(23)

The above equation further highlights the negative relationship and we use it to explore specific policy reforms of the union and and the conditions under which they would be welfare reducing for the non-union countries.

4.1 Reform of Union Trade Tariffs

Members of an environmental union can choose to set their environmental taxes at a certain level as per the terms of an agreement. If tax rates are not set at the optimal level, then the union can undertake a reform of their trade tariffs in order to benefit from a strict Pareto improvement in welfare. This may however have negative welfare effects on non-participating countries that can motivate policy makers in these countries to join the environmental union. This section aims to derive the conditions under which a Pareto improving reform of union trade tariffs can be welfare reducing for the non-union countries. For this purpose, we only look at a subset of possible reforms that could prove to be welfare reducing for the non-union countries. The specific case example highlights the role of a country’s terms of trade in deciding whether the reform is welfare reducing for it. The reform is extended from Proposition 8 and is set up such that it can be undertaken by all the union members uniformly or by just one of them.
Equation 23 can be written as:

$$\sum_{u=1}^{M} \hat{p'} E_{pu} du = \sum_{u=1}^{M} \left[ (\hat{t} - t^u)' G_{pp} du + (\hat{s} - s^u)' G_{sp} du \right] - \sum_{f=M+1}^{N} \hat{p'} E_{pf} df$$

(24)

**Proposition 9:** Let $\tilde{t}^u$ denote the (second best) optimal trade tariff for union country $u$ and assume that

$$(\hat{s} - s^u)' G_{sp} \left[ \tilde{t}^u - t^u \right] > 0$$

(25)

then a tariff reform in the direction

$$dt^u = \alpha \left[ \tilde{t}^u - t^u \right] \alpha > 0 \ u \in 1, M$$

which is chosen so as to ensure

$$\sum_{f=M+1}^{N} \hat{p'} E_{pf} df < 0 \ f \in M + 1, N$$

(26)

is strictly Pareto improving for the union.

This type of a tariff reform implies a proportional shift towards the (second best) optimal trade tariffs, defined as:

$$\tilde{t}^{u'} = \hat{t}' + (\hat{s} - s^u)' G_{sp} [G_{pp}^{-1}]$$

Thus, the second best optimal tariff for the union country includes the world shadow tariffs as well as a measure that accounts for the environmental distortion due to the difference in the existing environmental tax from its shadow price.\(^{30}\) Assumption 25 stems from the definition of environmentally damage intensive products that satisfy $(\hat{s} - s^u)' G_{sp} < 0.\(^{31}\) This condition states that a price induced expansion in the output of the $q$th good leads to larger emissions of the pollutants on which the

---

\(^{30}\)Given that the environmental policy of the union is unchanged, the optimal tariffs considered here are second best.

\(^{31}\)Copeland [1994] defines a good to be pollution intensive if $\partial z_i / \partial p_i > 0$. An increase in the price of good $i$ will increase its output by drawing resources away from the rest of the economy towards producers of good $i$. If, at the margin, the expanding part of the economy produces more pollution than the contracting part, $\partial z_i / \partial p_i > 0$ and the sector producing good $i$ is pollution intensive. $\partial z_i / \partial p_i$ can also be represented as $-G_{sp_i}$. 

21
taxes are initially low \((s_m - s_m^o > 0)\).\(^{32}\) Thus, assumption 25 implies that pollutants that are most damaging while lightly taxed, are, on average, emitted in the production of goods that are relatively more protected \([t_{n-q}^{\text{opt}} - t_{n-q}^o] < 0\).\(^{33}\) Condition 26 states that the reform is welfare reducing for the non-union country. Since there exists a negative relationship between the changes in welfare of the union and non-union countries, the union can choose a reform such that it will reduce the welfare of the non-member country. This condition along with the assumption, will ensure the strict Pareto improvement of the reform on the union’s welfare.

This proposition can be understood further by using a specific 3X3 example with simplifying assumptions. Let there be 3 countries, each being completely specialised in the production of one good and importing the other two. So, for instance, country 1 produces good 1 and imports good 2 and 3, and so on. The benefit of this assumption is that country level emissions originate from the production of a single good (good 1 in country 1, good 2 in country 2 and good 3 in country 3) and we can see how emissions in country 1 change as per changes in the prices of good 2 and 3, thus giving an indication of emissions leakage. Good 1 is assumed to be the numeraire with respect to which the prices of the other goods are expressed. In this example, we let the tariff reform be undertaken by the union countries (country 1 and 2), who leave their environmental policies unchanged whilst the non-union country (country 3) is policy passive. Upon opening the matrix and expanding the vector in 25 we get:

\[
(\hat{s} - s^1)' G_{s1p}^{1} [\hat{f}u - t^1] = (\hat{s} - s^1)' \left[ \begin{array}{ccc} 0 & \frac{\partial z_1}{\partial p_2} & \frac{\partial z_1}{\partial p_3} \\ \end{array} \right] \\
\end{array}=
\begin{array}{l}
\begin{pmatrix}
\hat{t}_1^1 - t_1^1 \\
\hat{t}_1^2 - t_1^2 \\
\hat{t}_1^3 - t_1^3
\end{pmatrix}
\end{array}
\]

\[
(\hat{s} - s^2)' G_{s2p}^{2} [\hat{f}u - t^2] = (\hat{s} - s^2)' \left[ \begin{array}{ccc} 0 & \frac{\partial z_2}{\partial p_2} & \frac{\partial z_2}{\partial p_3} \\ \end{array} \right] \\
\end{array}=
\begin{array}{l}
\begin{pmatrix}
\hat{t}_2^1 - t_2^1 \\
\hat{t}_2^2 - t_2^2 \\
\hat{t}_2^3 - t_2^3
\end{pmatrix}
\end{array}
\]

Further, we assume that country 1 and 2 that form the environmental union do not impose a trade tariff on each other \(t_1^1 = t_2^1 = t_1^2 = t_2^2 = 0\). This assumption is included to be able to reduce the vector of tariffs and enable a clearer impression of the reforms. Further, assume that the goods are substitutes in consumption. Then 25 reduces to the following for \(u = 1, 2\)

\(^{32}\)The matrix \(G_{s,p}\) provides information on how a change in relative price of good \(n\) leads to a change in emissions of pollutant \(m\) in country \(j\). If the increase in price of the \(n\)th good leads to an increase in the emissions of the \(m\)th pollutant, then the \(nm\)th element of the matrix is negative. The elements are assumed mostly negative as long as the good is pollution intensive.

\(^{33}\)Refer to Turunen Red and Woodland 2004.
There are now three cases that emerge depending on the difference in the environmental taxes from the shadow taxes.

**Case A:** Both the union countries have set their environmental taxes higher than the world shadow prices for emissions: \( \hat{s} - s^u < 0, \, u = 1, 2 \)

In this case, the impact of the reform depends on the cross price elasticities and the elasticities of substitution between goods 1, 2 and 3. Given the assumption that the pairs of goods: 1, 3 and 2, 3 are substitutes, then an increase in the price of good 3 would lead to consumer substitution into goods 1 and 2. This would lead to an increase in domestic production of these goods, which would lead to an increase in domestic emissions leading to \( \frac{dz_1}{dp_3} > 0 \) and \( \frac{dz_2}{dp_3} > 0 \). In this case, the Pareto-improving reform for the union would be an increase in their tariffs, \( dt^1 = \alpha \left[ \tilde{t}_3^1 - t_3^1 \right] > 0 \), \( dt^2 = \alpha \left[ (\tilde{t}_3^2) - t_3^2 \right] > 0 \) for any \( \alpha > 0 \). Intuitively, this means that as an environmental union raises its taxes to a higher level (than world shadow prices), it can reduce/eliminate trade tariffs within the union while imposing a tariff on the non-participating country. This tariff would be akin to a border tax adjustment which would seek to compensate the union for the difference in production costs (due to its high environmental standards) with the imports from countries that have lower production costs due to lower environmental standards.

**Case B:** \( (\hat{s} - s^1) > 0 \) and \( (\hat{s} - s^2) < 0 \)

If a member of the union sets its environmental tax higher than the world shadow prices (e.g. country 2) while the other sets its lower than the world shadow prices (country 1)\(^{34} \), then the tariff reform would involve a member increasing its tariffs, while the other decreasing it.

In this case, the 25 for country 1 = \(- (\hat{s} - s^1) \frac{dz_1}{dp_3} \left[ t_3^1 - t_3^1 \right] \) will be \( > 0 \) if the country imposes a tariff reform that reduces the difference between the initial tariff and the (second best) optimal tariffs \( dt^1 = \alpha \left[ t_3^1 - t_3^1 \right] < 0 \). For country 2 that has higher environmental taxes than the shadow taxes, the Pareto-improving tariff reform would be to decrease tariffs and impose a tariff on the non-union country such that \( dt^2 = \alpha \left[ (\tilde{t}_3^2) - t_3^2 \right] > 0 \). Thus, the direction of the tariff reform depends on the direction of the difference in the environmental tax from the shadow tax in the fulfilling of Proposition 25.

---

\(^{34}\)This could happen in a situation where union members differ in their level of development, e.g. if the more developed country sets a higher tax while its less developed counterpart sets a lower tax, as long as they agree to improve their environmental standards by joining the agreement.
Policy makers in developing countries often oppose carbon taxes on the basis that they could hamper economic growth (by increasing production costs, reducing profits, diminishing the competitiveness of exports, e.g. Aldy et al., 2010). Case B suggests that an environmental union that consists of developed countries that set higher environmental taxes and developing countries that are allowed to set lower taxes, can benefit from a strict Pareto-improvement in welfare through a tariff reform.

Case C: Both union countries set their environmental taxes lower than the world shadow prices for emissions \( s - s^u > 0, u = 1, 2 \)

Where the union countries have set lower environmental taxes than the world shadow taxes, then the welfare improving tariff reform is in the direction of reducing the difference between the existing tariff and the optimal tariffs, \( dt^1 = \alpha \left( \tilde{t}_1 - t_1^1 \right) < 0, \quad dt^2 = \alpha \left( \tilde{t}_2 - t_2^1 \right) < 0. \)

Thus, in all the above cases, the direction of the Pareto-improving tariff reform of the union depends on the direction of the difference in the environmental tax from the shadow tax. The policy implication of this relationship (25) is that if the union members set high environmental standards, they can still benefit from a Pareto welfare improvement by reducing or eliminating tariffs amongst each other while imposing a tariff on the non-union country (similar to a border tax adjustment). If the union members set lower environmental taxes (as compared to world shadow emission prices) then they can benefit by increasing their tariffs. Thus, if one policy variable is set at a higher level, under certain conditions, a Pareto-improvement in welfare can be attained by a reform that involves a decrease in the levels of the second policy variable. Therefore, under certain conditions, an environmental union 'allows' for free trade conditions within it.

The reform in all the cases A to C, has to satisfy the main condition 25 and will be unambiguously welfare improving for the union as long as it is welfare reducing for the non-union country. Thus, we now analyse the effects of the union’s policy changes on the non-union country.

The impact of the union tariff reform on the welfare change in country 3 can be arrived at by substituting for \( dt^1 \) and \( dt^2 \) and setting all other policy changes equal to zero in equation 21 to get:

\[
\left( p^3 - X^3 \right) E_{pu}^3 du^3 = +\alpha \left( \tilde{t}^3 - X^3 \right) S_{pp}^3 \left( \tilde{t}^1 - t_1^1 \right) - \alpha \left( \tilde{t}^3 - X^3 \right) \left( S_{pk}^3 + S_{pk}^2 + S_{pk}^3 \right) \left( \tilde{t}^1 - t_1^1 \right) - \alpha' \left( S_{pk}^3 \right) S_{sp}^1 \left( \tilde{t}^1 - t_1^1 \right) \left( E_{pu}^1 du^1 + E_{pu}^2 du^2 \right)
\]

The reform by the union has 2 effects on the non-participating country:

- A welfare improving effect : \( \left( \tilde{t}^3 - X^3 \right) S_{pp}^u \left( \tilde{t}^u - t^u \right) \), which provides the impact of the union’s terms of trade effects stemming from the change in the union’s tariffs.
- A welfare reducing effect from:
The indirect impact of a change in union’s tariffs on emissions (via changes in production allocations) and thus on global net compensated demand: 
\[
\left( t^3 - X^3 \right) \left( S^1_{pk} + S^2_{pk} + S^3_{pk} \right) S^u_{sp} \left( t^u - t^u \right)
\]

- The impact of a tariff reform on the compensated demand of country 3: 
\[
p' S^3_{pk} S^u_{sp} \left( t^u - t^u \right).
\]
The tariff reform that leads to an increase in production and hence emissions within union countries would negatively affect the compensated demand of consumers in country 3 and hence have an overall welfare reducing effect.

- The increase in welfare of the union countries \( \left\{ \left( t^3 - X^3 \right) \left( E^1_{pu} du^1 + E^2_{pu} du^2 \right) \right\} \) would lead to a welfare reducing effect on country 3, due to the negative relationship that emerges from the international trade balance.

Thus if the welfare reducing effects are greater than the welfare improving effect, then the union reform is overall welfare reducing for the non-participating country. The competing effects on country 3’s welfare stem from two sources: (a) the impact of the tariff reform on the union’s terms of trade and emissions (which in turn affect the global compensated demand), and (b) the difference between country 3’s pollution augmented shadow tariff \( \left( t^3 \right) \) and the pollution augmented net exports \( \left( X^3 \right) \).

For the case where the union imposes a tariff on the non-participating country \( t^u - t^u > 0 \) and assuming goods and a clean environment are substitutes in consumption, i.e \( S^1_{pk} + S^2_{pk} + S^3_{pk} < 0 \), the conditions for the union reform to be welfare reducing for country 3 reduce to:

- If the impact of a change in union emissions on global compensated demand exceeds the impact of the change in prices on the union’s terms of trade. Intuitively, the change in union emissions due to the change in tariffs (prices) can be viewed as an emissions leakage effect. If the union’s decrease in tariffs causes a decrease in their emissions, this would correspond to a negative leakage within the union.

- The \( \left( t^3 - X^3 \right) \) captures the terms of trade effect of country 3 and the effect of global emissions leakage on compensated demand of country 3 \( \left[ E^3_{pk} \left( S^1_{uw} + S^2_{uw} + S^3_{uw} \right) \right] \). If the emissions leakage effect dominates the terms of trade effect, then \( \left( t^3 - X^3 \right) > 0 \).

Thus, in a nutshell, the union reform will be welfare reducing for the non-participating country, if the emissions leakage effect exceeds the terms of trade effect. While the non-union country may benefit from an increase in comparative advantage associated with lower production costs from lower environmental standards (terms of trade effect), the union’s high environmental standards allows it to reduce/eliminate tariffs in a manner that increases the union’s domestic production and eventually
emissions. This leads to the (domestic) emissions leakage effect that negatively affects the compensated demand of country 3 and hence its welfare.

Impact on Pollution

In the above analysis, we showed that the union tariff reform may lead to a production allocation within the union that can have the indirect effect of increasing emissions within the union – a situation which would be counter-productive to the purpose of an environmental union. This section briefly analyses the effect of the reform on a change in global pollution using the 3X3 case.

Differentiating equation 6 and substituting for $dw$ using the perturbation of equation 3

$$dk = \begin{bmatrix}
(S_{sw}^1 + S_{sw}^2 + S_{sw}^3) R^{-1}_{ww} (S_{wu}^1 du^1 + S_{wu}^2 du^2 + S_{wu}^3 du^3) \\
+ (S_{sw}^1 + S_{sw}^2 + S_{sw}^3) R^{-1}_{ww} \{ S_{wp}^1 - \left( S_{wk}^1 + S_{wk}^2 + S_{wk}^3 \right) S_{sp}^1 \} dt^1 \\
+ (S_{sw}^1 + S_{sw}^2 + S_{sw}^3) R^{-1}_{ww} \{ S_{wp}^2 - \left( S_{wk}^1 + S_{wk}^2 + S_{wk}^3 \right) S_{sp}^2 \} dt^2 \\
\end{bmatrix} - S_{sw}^1 dt^1 - S_{sw}^2 dt^2$$

Initially, the union countries increase their environmental standards and raise their environmental taxes from some level to $s^1$ and $s^2$ which increase their costs of production, causing producers to charge a higher output price. Since countries specialise in and export one good, their domestic price is the world price and hence there is an increase in $dw^2 > 0$, while the price of good 1 (numeraire) remains unchanged, its value has increased. Given that country 3 is assumed to leave its environmental policy unchanged, thereby leaving domestic production costs unchanged, the price of good 3 is now only affected by the increase in the value of the numeraire. This leads to a decrease in its price with $dw^3 < 0$.

The matrix is given by $S_{sw}^1 = \begin{bmatrix} 0 & \partial G_{s1}^1 / \partial w^2 & \partial G_{s1}^1 / \partial w^3 \end{bmatrix}$, where due to substitutability between goods, $\partial G_{s1}^1 / \partial w^2 < 0$ or $\partial G_{s1}^1 / \partial w^2 > 0$ indicates a positive emissions leakage effect. Similarly, the decrease in price of good 3 due to the increase in production cost of the numeraire, indicates a negative emissions leakage effect. Similarly, the impact of union’s environmental policy, via change in prices would affect emissions in the non-union country as given by: $S_{sw}^3 = \begin{bmatrix} 0 & \partial G_{sw}^3 / \partial w^2 & \partial G_{sw}^3 / \partial w^3 \end{bmatrix}$. The terms $\partial G_{sw}^3 / \partial w^2 < 0$ and $\partial G_{sw}^3 / \partial w^3 < 0$ indicate that as the price of 2 rises (due to the increase in environmental taxes), the substitutability between goods implies that country 3 increases its domestic production of good 3 thus increasing its emissions. Simultaneously, the decrease in the price of good 3 (due to the increased value of the numeraire good 1), leads to consumer substitution away from good 1 (whose price is unchanged) towards good 3 which contributes towards an increased production and hence emissions. These terms clearly show the positive emissions leakage effect in the non-union country. Thus, $(S_{sw}^1 + S_{sw}^2 + S_{sw}^3)$

\[35\] An increase in the value of the numeraire good implies a decrease in the price of the other goods (Reis & Watson 2007). An increase in the unit cost of production of the numeraire good leads to an increase in its value (Curzi & Pellizzari 1999, Baranzani et al 2015).
will be negative and indicates global emissions leakage in the case where each country fully specialises in one good.

Using the earlier assumption that goods and a clean environment are substitutes in consumption implies that $R_{ww}$ is positive. Further, $S_{sp}^u$ is negative. Thus, the change in global pollution is affected by four effects, two direct and two indirect effects as explained below:

- Indirect effect through the impact of emissions leakage on changes in welfare
  \[ (S_{sw}^1 + S_{sw}^2 + S_{sw}^3)R_{ww}^{-1}(S_{wu}^1du^1 + S_{wu}^2du^2) \]
  - Environmental policy affects prices and hence demand. Furthermore, through emissions leakages the change in welfare affects global pollution changes. If the increase in welfare of the union is greater than the magnitude of the decrease in welfare of the non-union country, then this effect will have a pollution reducing effect.

- Direct effect through change in prices on terms of trade
  \[ (S_{sw}^1 + S_{sw}^2 + S_{sw}^3)R_{ww}^{-1}(S_{wp}^1dt^u) \]
  - Changes in tariffs affect prices that directly affect the terms of trade of the country. This change in terms of trade augmented with the pollution augmented world trade matrix and global emissions leakage effect directly affects the change in pollution. This effect reduces pollution as long as the change in prices improve the terms of trade of the union countries. The reason for this relationship being is that the terms of trade of the countries that have more stringent environmental policies improve, then their negative emissions leakage outweighs the non-union's positive emissions leakage such that there is an overall pollution decreasing effect.

- Direct effect through changes in domestic emissions
  \[ -S_{sw}^u dt^u \]
  - Change in tariffs cause a change in domestic prices which affect domestic production allocations and thus cause changes in domestic emissions. A decrease in domestic emissions by the union have an opposite effect on the pollution because of the negative leakage effect from the non-union countries.

- Indirect effect through changes in emissions on compensated demand
  \[ -((S_{sw}^1 + S_{sw}^2 + S_{sw}^3)R_{ww}^{-1}(S_{wk}^1 + S_{wk}^2 + S_{wk}^3))S_{wu}^u dt^u \]
The above direct effect on domestic emissions further affect global compensated demand which combined with the global emissions leakage effect have an pollution increasing effect. This is because the greater the emissions, the greater the demand for goods (given the substitutability between goods and clean environment), which ultimately lead to increased production and increased emissions.

Thus, the overall impact of a union tariff reform on a change in global pollution depends on which of the above effects dominate. If the emissions leakage effect on welfare and union’s terms of trade dominate the direct effects of union emissions and indirect effect on compensated demand, then the tariff reform would lead to a reduction in pollution. If however, the reverse occurs, then the tariff reform would lead to an increase in global pollution.

4.2 Reform of Union Environmental Taxes

The countries that are a part of the environmental union may set their initial environmental taxes at non-optimum levels. They can therefore benefit from a strict Pareto-improvement in their welfare by undertaking a reform of their environmental taxes. This reform can be simultaneously welfare reducing for the non-union countries due to the relationship in equation 23. To explore this, we examine only a subset of reforms that would be welfare improving for the union while being welfare reducing for the non-union country. As in the previous section, we assume that the non-union country is policy passive and the union undertakes only environmental policy changes and leaves its tariffs unchanged (thus the optimal environmental tax is second best). The reform is extended from Proposition 6 and is set up such that it can be undertaken by all the union members uniformly or by just one of them.

Proposition 10: Let \( \hat{s}^u \) denote the (second best) optimal environmental tax for union country \( u \) and assume that

\[
\begin{align*}
\left( \hat{\nu} - t^u \right)^T G_{ps}^u \left( \hat{s}^u - s^u \right) > 0
\end{align*}
\]

then an environmental tax reform in the direction

\[
\begin{align*}
ds^u = \delta \left( \hat{s}^u - s^u \right) \quad &\delta > 0
\end{align*}
\]

which is chosen so as to ensure

\[
\sum_{f=M+1}^N \hat{\nu}^f E_{pu}^f du^f < 0,
\]

is strictly Pareto improving for the union country.
The reform implies a shift of environmental taxes towards the (second best) optimal levels; where the second best optimal environmental tax is given by: $s^{u'} = s' + (\hat{t} - t^u)' G_{ps} [G_{ss}]^{-1}$. This second best optimal tax includes the value of the shadow price for emissions and an adjustment factor that accounts for the impact of environmental policy on production augmented by the initial difference between the existing tariff and the shadow tariff.\footnote{$s^{u'}$ is qualitatively consistent with Kotsogiannis and Woodland (2013) and Turunen-Red and Woodland (2004).}

Condition 27 states that the damage intensities of the goods (represented by $G_{ps} (s^u - s^u)$) are on average, positively correlated with the country specific trade distortions $(\hat{t}' - t^u)$. This condition holds when the pollutants that are most damaging while lightly taxed (i.e. emissions $m$ for which $s_m^u - s_m > 0$) are emitted in the production of goods that are relatively highly protected (goods $q$ for which $\hat{t}_q - t_q^u < 0$). Thus, the condition implies that if the existing union tariffs are at a higher level (than shadow tariffs) then the tax reform should be a reduction in environmental taxes. Conversely, if the tariffs are set lower, the reform allows for the possibility to set higher environmental taxes. The reform will be strictly Pareto-improving for the union countries as long as condition 27 holds and the reform is welfare reducing for the non-union countries. This can be better understood using the earlier example of 3 countries. Using the same production and trade assumptions of the earlier example, the condition 27 opens up to:

$$
\left(\hat{t}' - t^u\right)' G_{ps} (s^u - s^u) = \left[ \begin{array}{c} t_1^u - t_1^u \\ t_2^u - t_2^u \\ t_3^u - t_3^u \end{array} \right]' \left[ \begin{array}{c} d y_1^u \\ d y_2^u \\ d y_3^u \end{array} \right] \left[ s^u - s^u \right]
$$

Further, assuming that countries $1$ and $2$ do not impose a trade tariff on each other $t_1^1 = t_1^2 = 0$, the above for $u = 1, 2$ reduces to:

$$
\left(\hat{t}' - t^1\right)' G_{ps}^1 (s^1 - s^1) = \left[ \begin{array}{c} t_1^1 - t_1^1 \\ t_3^1 - t_3^1 \end{array} \right]' \left[ \begin{array}{c} d y_1^1 \\ d y_3^1 \end{array} \right] \left[ s^1 - s^1 \right]
$$

and

$$
\left(\hat{t}' - t^2\right)' G_{ps}^2 (s^2 - s^2) = \left[ \begin{array}{c} t_3^2 - t_3^2 \end{array} \right]' \left[ \begin{array}{c} d y_3^2 \end{array} \right] \left[ s^2 - s^2 \right]
$$

There are now three cases that emerge depending on the direction of the difference of the initial tariff from the shadow tariffs within the union countries.

Case A: Both union countries impose high tariffs on the non-union country

This implies that $(t_1^1 - t_1^1) < 0$, $(t_2^1 - t_2^1) < 0$ and tariffs imposed on the imports from country $3$ by the union countries are higher than what they should be (shadow tariffs) after accounting for trade...
and environmental distortions. Given the assumption of substitutability between the goods, a high import tariff on good 3 implies trade protection of the domestic production within the union countries. Given that \( \frac{dx_1}{dx_3} < 0 \) and \( \frac{dx_2}{dx_3} < 0 \), a reform of the type \( ds^1 = \delta \left( \tilde{s}^1 - s^1 \right) > 0 \), \( ds^2 = \delta \left( \tilde{s}^2 - s^2 \right) > 0 \) that reduces the environmental tax would be welfare improving for the union. This is analogous to case A of the tariff reform, where if one policy variable is already set high by the union, the welfare reform is to reduce the second policy variable.

Case B: \( \left( \tilde{t}_3 - t_3 \right) < 0 \) and \( \left( \tilde{t}_3 - t_3 \right) > 0 \)

In this case, country 1 imposes a higher tariff on country 3 while country 2 imposes a lower tariff, as compared to the shadow tariffs. This would mean that, for country 1, the environmental reform would be to decrease the tax while for country 2 it would mean to increase the environmental tax, as long as all the goods are substitutes and pollution intensive. For country 1, the reform takes the direction \( ds^1 = \delta \left( \tilde{s}^1 - s^1 \right) > 0 \) while for country 2 it takes the direction \( ds^2 = \delta \left( \tilde{s}^2 - s^2 \right) < 0 \). Thus, in the case where the direction of the differences between the tariffs imposed from the shadow tariffs of the union countries differ, the optimal environmental tax reform also differs in the direction and it depends on the condition 27 being fulfilled. If the condition is reversed, the direction of the reform is reversed too.

Case C: Both union countries set lower tariffs than the shadow tariffs \( \left( \tilde{t}_3 - t_3 \right) > 0 \), \( \left( \tilde{t}_3 - t_3 \right) > 0 \)

In this case, the tariffs imposed by the union countries do not appropriately account for the trade and environmental distortions from country 3. For the condition 27 to be fulfilled, the reform takes the direction of \( ds^1 = \delta \left( \tilde{s}^1 - s^1 \right) < 0 \) and \( ds^2 = \delta \left( \tilde{s}^2 - s^2 \right) < 0 \), or reducing the difference between the optimal tax and the existing environmental taxes. An interesting policy implication of this case is that countries that are bound by free trade agreements, or those that enjoy mutually low tariffs, can 'afford' to set higher environmental standards and still benefit from an increase in their welfare.

The above cases will be unambiguously welfare improving for the union as long as the policy is welfare reducing for the non-union country. Thus, we now analyse the impact of the reform on the changes in welfare of the non-union country, by substituting for \( ds^1 \) and \( ds^2 \) and setting all other policy changes equal to zero in equation 21 to get:

\[
\delta \left( \tilde{t}^3 - X^3 \right) S^1_{ps} \left( \tilde{s}^1 - s^1 \right) - \delta \left( \tilde{t}^3 - X^3 \right) \left( S^1_{pk} + S^2_{pk} + S^3_{pk} \right) S^1_{ss} \left( \tilde{s}^1 - s^1 \right) - \delta p' S^3_{pk} S^1_{ss} \left( s^1 - \left( \tilde{t}^3 - X^3 \right) E^3_{pu} du^3 = + \delta \left( \tilde{t}^3 - X^3 \right) S^2_{ps} \left( \tilde{s}^2 - s^2 \right) - \delta \left( \tilde{t}^3 - X^3 \right) \left( S^1_{pk} + S^2_{pk} + S^3_{pk} \right) S^2_{ss} \left( \tilde{s}^2 - s^2 \right) - \delta p' S^3_{pk} S^2_{ss} \left( s^2 - \left( \tilde{t}^3 - X^3 \right) E^2_{pu} du^2 \right) \right) - \left( \tilde{t}^3 - X^3 \right) \left( E^1_{pu} du^1 + E^2_{pu} du^2 \right) \right) + \delta p' \left( \tilde{s}^3 - s^3 \right) \left( \tilde{t}^3 - X^3 \right) \left( E^3_{pu} du^3 + E^2_{pu} du^2 \right) - \delta \left( \tilde{t}^3 - X^3 \right) \left( E^1_{pu} du^1 + E^2_{pu} du^2 \right) \right)
\]

Thus, the union’s environmental reform has competing effects on the change in welfare of country 3. These effects depend on the direction of the reform – and, as the direction reverses, so also does the effect. For an environmental reform in the direction of increasing environmental taxes, or reducing the
difference from the optimal tax \( ds^u = \delta (s^u - \tilde{s}^u) < 0 \), the following are the effects on the non-union country, when goods and clean environment are substitutes in consumption \( \left( S^1_{pk} + S^2_{pk} + S^3_{pk} < 0 \right) \):

- Welfare improving effect: \( \left( \hat{t}^3 - X^3 \right) S^u_{ps} \left[ \tilde{s}^u - s^u \right] \), which provides the effect of a change in country \( u \)'s environmental taxes on its terms of trade. If the union country increases its environmental tax, it reduces its domestic production \( S^u_{ps} < 0 \), and thus imports more from country 3 (goods 1 and 3 being substitutes) to meet the shortfall in the domestic demand (which may remain the same if output prices are unchanged), and thereby leading to a welfare improving effect on the non-union country. This term captures the emissions leakage that occurs from the terms of trade impact of the tax reform.

- Welfare decreasing effects from:
  
  - The impact of a change in the union country’s environmental tax on global compensated demand (due to a change in emissions): \( \left( \hat{t}^3 - X^3 \right) \left( S^1_{pk} + S^2_{pk} + S^3_{pk} \right) S^u_{ss} \left[ \tilde{s}^u - s^u \right] \)
  
  - The impact of the tax reform on emissions and thus on the net compensated demand of country 3: \( p' \left( S^3_{pk} \right) S^u_{ss} \left[ \tilde{s}^u - s^u \right] \)
  
  - The increase in welfare of the union countries \( \left\{ \left( \hat{t}^3 - X^3 \right) \left( E^1_{pu,du} + E^2_{pu,du} \right) \right\} \) would lead to a welfare reducing effect on country 3, due to the negative relationship that emerges from the international trade balance.

Thus, if the welfare reducing effects are greater than the welfare improving effect, then the union reform is overall welfare reducing for the non-participating country. Similar to the case of the impact of tariff reform, the competing effects on the welfare of the non-union country come from (a) the impact of the environmental tax reform on the union’s terms of trade and its emissions and thereby the global compensated demand; (b) the difference in between country 3’s pollution augmented shadow tariff from its net exports. For the case where the union increases its environmental taxes, the reform will be welfare reducing for the non-union country if:

- The emissions leakage from the union’s terms of trade impact of the reform is outweighed by the direct effect of a change in union’s emissions on global compensated demand.

- The \( \left( \hat{t}^3 - X^3 \right) \) captures the terms of trade effect of country 3 and the effect of global emissions leakage on compensated demand of country 3 \( \left[ E^3_{pk} \left( S^1_{sw} + S^2_{sw} + S^3_{sw} \right) \right] \). If the emissions leakage effect dominates the terms of trade effect, then \( \left( \hat{t}^3 - X^3 \right) > 0 \).
Therefore, the union’s environmental reform will be welfare reducing for the non-participating country, if the global emissions leakage effect exceeds the country’s terms of trade effect, or if the union’s (negative) emissions leakage effect exceeds the union’s terms of trade effect. Country 3 will benefit from an increase in comparative advantage associated with the union’s increased production costs from an increase in their environmental standards, which leads to an increase in country 3’s production and exports (terms of trade effect). Simultaneously, however, the change in union emissions (negative leakage) and the non-union’s emissions (positive leakage) affects global compensated demand which leads to a welfare reducing impact on country 3. Thus, if the emissions leakage effect on compensated demand dominates the welfare improving terms of trade effect, the union’s reform will be overall welfare reducing for the non-union country.

Impact on Pollution

The above analysis indicates that the union emissions may decrease as a result of the environmental tax reform, while through the terms of trade, there might be a positive emissions leakage effect in country 3, leading to the question of the overall impact on global pollution. In this section we use the 3X3 case to analyze the effect of the union’s environmental reform on the change in global pollution.

Differentiating equation 6 and substituting for $dw$ using the perturbation of equation 3, we obtain an expression for the change in global pollution as a function of a change in welfare and union’s environmental policy.

$$dk = \left[ \begin{array}{c} (S_{1w} + S_{2w} + S_{3w}) R_{ww}^{-1} (S_{1w} du^1 + S_{2w} du^2 + S_{3w} du^3) \\ + (S_{1w} + S_{2w} + S_{3w}) R_{ww}^{-1} \{S_{1s} - (S_{1k} + S_{2k} + S_{3k}) S_{1s} \} ds^1 \\ + (S_{1w} + S_{2w} + S_{3w}) R_{ww}^{-1} \{S_{2s} - (S_{1k} + S_{2k} + S_{3k}) S_{2s} \} ds^2 \end{array} \right] - S_{ss} ds^1 - S_{ss} ds^2$$

The matrix $S_{sw}$ that gives the impact of a change in world prices on country level emissions is an indicator of emissions leakage effect through changes in prices. As explained earlier, the global leakage effect that aggregates the negative and positive emissions leakage effect due to a change in world prices from the change in union’s environmental policies is given by $(S_{1w} + S_{2w} + S_{3w})$ and is negative. The impact of environmental policy on a country’s production is given by the matrix $S_{sw}$. Since each country produces one good, an increase in emissions tax increases the cost of production and hence reduces the domestic production, making $S_{sw}$ negative. The impact of a change in emissions on global compensated demand (valued at world prices) is given by $(S_{1k} + S_{2k} + S_{3k})$ and is negative as long as the consumption of goods and clean environment are substitutes. The change in global pollution is a mix of direct and indirect effects as explained below:

- Indirect effect of emissions leakage via changes in welfare $(S_{1w} + S_{2w} + S_{3w}) R_{ww}^{-1} (S_{1w} du^1 + S_{2w} du^2 + S_{3w} du^3)$.
Changes in environmental policy affect prices and through them consumer demand and welfare. Furthermore, changes in prices affect emissions leakage which affects global pollution. If the increase in welfare of the union is greater than the decrease in welfare of the non-union country, then this effect will work towards a reduction of global pollution.

- **Indirect effect of emissions leakage via changes in domestic production** \( (S_{sw}^1 + S_{sw}^2 + S_{sw}^3) R_{ww}^{-1} (S_u^u d s^u) \)

- A change in environmental tax affects costs of production and hence affects domestic production. A decrease in domestic production may be accompanied by an increase in foreign production of a substitute good (emissions leakage). The final impact of a change in production allocations compounded by the global emissions leakage effect is given by the above term. An increase in union’s emissions tax would lead to a decrease in union’s emissions but an increase in non-union’s production and hence emissions; hence, this term has a pollution increasing effect.

- **Direct effect of the environmental reform on the union’s emissions** \(-S_{su} u d s^u\)

- An increase in environmental taxes increases production costs, decreases production and therefore decreases emissions which lead to a pollution reducing effect.

- **Direct effect of emissions leakage on compensated demand** \(- (S_{sw}^1 + S_{sw}^2 + S_{sw}^3) R_{ww}^{-1} (S_{wk}^1 + S_{wk}^2 + S_{wk}^3) S_{su}^u d s^u\)

- Change in environmental tax causes a change in domestic (union) emissions, while due to emissions leakage also affects global emissions. This in turn affects global compensated demand. An increase in union’s environmental tax causes this term to be pollution reducing.

Therefore, the final impact of a union environmental reform on global pollution depends on which of the above effects dominate. If the emissions leakage effect on changes in welfare and global compensated demand and the direct effect on union’s emissions exceed the impact of emissions leakage via changes in union’s production, then global pollution would decrease. However, if the emissions leakage via changes in production dominates over all other effects, then despite an increase in union’s environmental tax, there would be an increase in global pollution.
Concluding Remarks

In the derivation of the union’s first best optimal trade and environmental policies, we find that the presence of international transfers internalise the impact of the negative externalities stemming from the non-union countries, which leads to the optimal policies being closer in nature to a globally (fully) cooperative case. This implies that the environmental union may prefer to limit the transfers to within the union so as to not bear the burden of the marginal damage caused to consumers in the non-union countries. Whether limiting the international transfers is politically feasible is another matter. Specific policy reform proposals suggest that an environmental union that raises its environmental standards can reduce intra-union tariffs or have free trade within the union. Alternatively, the reforms also suggest that countries within a free trade agreement can afford to set more stringent environmental standards.

In the presence of both trade and environmental policies to address the corresponding distortions, there still exists a negative relationship between the changes in welfare of the union and non-union countries. This negative relationship stems from the international trade balance and highlights the role of the terms of trade in the union’s policy reforms that can lead to an increase in welfare for the union while ensuring a decrease in welfare of the non-union countries. The case example highlights the terms of trade conditions under which, despite the emissions leakage effect benefitting the non-union country, the latter faces a decrease in welfare as a result of the union’s policy reforms. The impact of the reform on pollution indicates that despite the environmental union raising their emissions taxes, under certain conditions, global emissions may increase. This increase would bring into question the importance of the choice of countries (including their size, the pollution intensities of the firms within them), that form the union versus those that are excluded; and could form the basis of future research.
References


Appendix:

Existence of Pareto improving reforms

Differentiate equations 3 to 8 to get respectively:

\[ \sum_{j=1}^{N} S_{w}^{j} dw + \sum_{j=1}^{N} S_{w}^{j} dw + \sum_{j=1}^{N} S_{wp}^{j} dt + \sum_{j=1}^{N} S_{w}^{j} ds + \sum_{j=1}^{N} S_{wk}^{j} dk = 0_{Q-1} \]
\[
\sum_{u=1}^{M} p'u S_{pu}^{u} du + \sum_{u=1}^{M} p'u S_{pu}^{u} dw + \sum_{u=1}^{M} S_{wu}^{u} dw + \sum_{u=1}^{M} p'u S_{pu}^{u} dt + \sum_{u=1}^{M} p'u S_{pu}^{u} ds + \sum_{u=1}^{M} p'u S_{pu}^{u} dk - \sum_{u=1}^{M} db^u = 0
\]

\[
p'S_{pu}^{f} du + p'S_{pu}^{f} dw + S_{wu}^{f} dw + p'S_{pu}^{f} dt + p'S_{pu}^{f} ds + p'S_{pu}^{f} dk - db^f = 0 \quad f = M + 1, \ldots, N
\]

\[
\sum_{j=1}^{N} S_{wu}^{j} dw + \sum_{j=1}^{N} S_{wu}^{j} dt + \sum_{j=1}^{N} S_{wu}^{j} ds + dk = 0
\]

\[
\sum_{j=1}^{N} db^j = 0
\]

The above differential comparative system can be expressed as equation 9 where the matrices A to F are defined by:

\[
A = \begin{bmatrix}
S_{wu}^1 & S_{wu}^2 & \ldots & S_{wu}^M & S_{wu}^{M+1} & \ldots & S_{wu}^N \\
p'S_{pu}^1 & p'S_{pu}^2 & \ldots & p'S_{pu}^M & 0 & \ldots & 0 \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
p'S_{pu}^1 & p'S_{pu}^2 & \ldots & p'S_{pu}^M & 0 & \ldots & 0 \\
0 & 0 & \ldots & 0 & p'S_{pu}^{M+1} & 0 & 0 \\
0 & 0 & 0 & 0 & \ldots & p'S_{pu}^{M+2} & 0 \\
0 & 0 & \ldots & 0 & 0 & 0 & p'S_{pu}^N \\
0 & 0 & \ldots & 0 & 0 & 0 & 0 \\
0 & 0 & \ldots & 0 & 0 & 0 & 0
\end{bmatrix}_{(N+3)x(N)}
\]
\[ B = \begin{bmatrix}
S_{ww}^1 + S_{ww}^2 + \ldots + S_{ww}^N \\
p'S_{pw}^1 + p'S_{pw}^2 + \ldots + p'S_{pw}^M + S_{ww}^1 + S_{ww}^2 + \ldots + S_{ww}^N \\
p'S_{pw}^1 + p'S_{pw}^2 + \ldots + p'S_{pw}^M + S_{ww}^1 + S_{ww}^2 + \ldots + S_{ww}^N \\
\vdots \\
p'S_{pw}^M + S_{ww}^1 + S_{ww}^2 + \ldots + S_{ww}^N \\
p'S_{pw}^{M+1} + S_{ww}^1 + S_{ww}^2 + \ldots + S_{ww}^N \\
p'S_{pw}^{M+2} + S_{ww}^1 + S_{ww}^2 + \ldots + S_{ww}^N \\
\vdots \\
p'S_{pw}^N + S_{ww}^1 + S_{ww}^2 + \ldots + S_{ww}^N \\
S_{sw}^1 + S_{sw}^2 + \ldots + S_{sw}^N \\
0
\end{bmatrix}
\]

\[ C = \begin{bmatrix}
S_{wp}^1 & S_{wp}^2 & \ldots & S_{wp}^M & S_{wp}^{M+1} & \ldots & S_{wp}^N \\
p'S_{pp}^1 & p'S_{pp}^2 & \ldots & p'S_{pp}^M & 0 & 0 & 0 \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
p'S_{pp}^1 & p'S_{pp}^2 & \ldots & p'S_{pp}^M & 0 & 0 & 0 \\
0 & 0 & \ldots & 0 & 0 & 0 & 0 \\
0 & 0 & \ldots & 0 & 0 & 0 & 0 \\
\cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\
S_{sp}^1 & S_{sp}^2 & \ldots & S_{sp}^M & S_{sp}^{M+1} & \ldots & S_{sp}^N \\
0 & 0 & \ldots & 0 & 0 & 0 & 0
\end{bmatrix}
\]

\[ D = \begin{bmatrix}
S_{ws}^1 & S_{ws}^2 & \ldots & S_{ws}^M & S_{ws}^{M+1} & \ldots & S_{ws}^N \\
p'S_{ps}^1 & p'S_{ps}^2 & \ldots & p'S_{ps}^M & 0 & 0 & 0 \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
p'S_{ps}^1 & p'S_{ps}^2 & \ldots & p'S_{ps}^M & 0 & 0 & 0 \\
0 & 0 & \ldots & 0 & 0 & 0 & 0 \\
0 & 0 & \ldots & 0 & 0 & 0 & 0 \\
\cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\
S_{ss}^1 & S_{ss}^2 & \ldots & S_{ss}^M & S_{ss}^{M+1} & \ldots & S_{ss}^N \\
0 & 0 & \ldots & 0 & 0 & 0 & 0
\end{bmatrix}
\]

\[ (N+3) \times (N) \]

38
Proof of Proposition 1:

Let $y$ be partitioned as $\begin{bmatrix} y_1' & y_2' & y_3 & y_4 \end{bmatrix}$ where $y_1 \in R^{Q-1}$, $y_2 \in R^N$, $y_3 \in R$ and $y_4 \in R$.

$$y'A^U = \begin{bmatrix} y_1' S_{ww}^u + y_2' p' S_{wp}^u \end{bmatrix} \leq 0 \quad u = 1, ..., M$$

$$y'A^* = \begin{bmatrix} y_1' S_{ww}^f + y_2' p' S_{wp}^f \end{bmatrix} \leq 0 \quad f = M + 1, ..., N$$

In equation 28, the vector $y_2'^U$ refers to $\left( \sum_{u=1}^M y_2'^u \right)$.

$$y'B = \begin{bmatrix} y_1' \sum_{j=1}^N S_{ww}^j + y_2' \sum_{u=1}^M (p' S_{wp}^u + S_{ww}^u) + \sum_{f=M+1}^N y_2' (p' S_{wp}^f + S_{ww}^f) + y_3 \sum_{j=1}^N S_{sw}^j \end{bmatrix} = 0$$

$$y'C^U = \begin{bmatrix} y_1' S_{wp}^u + y_2' p' S_{pp}^u + y_3' S_{sw}^u \end{bmatrix} = 0 \quad u = 1, ..., M$$
\[ y'C^* = \begin{bmatrix} y_1' S_{wp}^f + y_2' p' S_{pp}^f + y_3' s' S_{sp}^f \end{bmatrix} = 0 \quad f = M + 1, \ldots, N \] (32)

\[ y'D^U = \begin{bmatrix} y_1' S_{ws}^u + y_2' p' S_{ps}^u + y_3' s' S_{ss}^u \end{bmatrix} = 0 \quad u = 1, \ldots, M \] (33)

\[ y'D^* = \begin{bmatrix} y_1' S_{ws}^f + y_2' p' S_{ps}^f + y_3' s' S_{ss}^f \end{bmatrix} = 0 \quad f = M + 1, \ldots, N \] (34)

\[ y'E = \begin{bmatrix} y_1' \sum_{j=1}^{N} (S_{wk}^j) + y_2' \sum_{u=1}^{M} \left(p' S_{pk}^u \right) + \sum_{f=M+1}^{N} y_2' p' S_{pk}^f + y_3 \end{bmatrix} = 0 \] (35)

\[ y'F^U = \left[ -y_2' + y_4 \right] = 0 \] (36)

\[ y'F^* = \left[ -y_2' + y_4 \right] = 0 \] (37)

Assuming the system of equations concerning the non-union members has a solution, i.e., equations 29, 30, 32, 34, 35 and 37 have a solution. Thus, the conditions necessary for the existence of a pareto improving reform for the union countries is if there exists no solution to the equations 28, 30, 31, 33, 35 and 36.

Using equations 36 we get:

\[ y_2' = y_4 \]

Substitute this in equation 35 and get:

\[ y'_3 = -y'_1 \sum_{j=1}^{N} (S_{wk}^j) - y_4 p' \sum_{j=1}^{N} (S_{pk}^j) \] (38)

Using market clearing condition 3 and substituting \( y'_3 \) from equation 38 into equation 30 we get:

\[ y'_1 = -y_4 p' R_{pw} (R_{ww})^{-1} \] (39)

Substitute equations 39 and 38 into equation 31

\[ y_4 p' S_{pp}^u + y_4 s' S_{sp}^u = 0 \]

Substitute equations 39 and 38 into equation 33
\[
y_4 \hat{p}' S_{ps}^u + y_4 \hat{s}' S_{ss}^u = 0
\]

Substitute equation 39 into equation 28

\[
y_4 \hat{p}' S_{pu}^u \leq 0
\]

If the reform is undertaken unilaterally by a union member, then for strict Pareto improving reforms, the above condition becomes \( y_4 \hat{p}' S_{pu}^u < 0 \)

Thus, if there exists no scalar \( y_4 \) that solves the following conditions, then there exists a strictly pareto improving set of tariff and/or tax reforms for the union:

\[
y_4 \hat{p}' S_{pu}^u \leq 0 \quad u = 1, ..., M
\]

\[
y_4 \hat{p}' S_{pp}^u + y_4 \hat{s}' S_{sp}^u = 0
\]

\[
y_4 \hat{p}' S_{ps}^u + y_4 \hat{s}' S_{ss}^u = 0
\]

Define \( \mu = y_4 \) and \( \beta^u = \hat{p}' S_{pu}^u \) to get proposition 3

**Proof of Corollary 3.1**

If at least one nation satisfies generalised Hatta normality condition, \( \beta^u < 0 \), then that implies \( \mu \neq 0 \). Thus the system of equations represented by equation 9 will have a solution if for all union countries \( u = 1, ..., M \), the following hold:

\[
\hat{p}' S_{pp}^u + \hat{s}' S_{sp}^u = 0
\]

and

\[
\hat{p}' S_{ps}^u + \hat{s}' S_{ss}^u = 0
\]

Conversely, if \( \hat{p}' S_{pp}^u + \hat{s}' S_{sp}^u \neq 0 \) and \( \hat{p}' S_{ps}^u + \hat{s}' S_{ss}^u \neq 0 \), for at least one union country, then the system is not at optimum, and there exists a strictly Pareto improving reform of union policy.