Welfare and Trade Effects of Regional Environmental Agreements

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Abstract

Abstract:

This is a preliminary version of the paper that seeks to explore the welfare effects of environmental policy arising from a regional environmental agreement on the participating and non-participating countries. By doing so, this paper aims to shed light on the potential incentives for a country to join an environmental agreement (referred to as an environmental union). Specifically, we modify an N-country-Q-goods general equilibrium framework under free-trade conditions to study the cooperative and unilateral policy settings and thereafter country-specific and fully harmonized policy settings within the union. The terms of trade of a country have emerged to be the key factor that influences the relationship between welfare changes of the union and non union countries.

1 Introduction

Over the past few years there is a growing concern over climate change and its potentially disastrous ramifications on the welfare of future generations. There has emerged a consensus that increased economic activity is one of the major contributors to the worsening of the environment.[1] Particularly, the focus has been on international trade as the lead contributor to increased green house gas emissions (due to transportation, increased production). There is a complex system of linkages and feedback effects between international trade (and trade policy) and the environment (and environmental policies). The sources of emissions and the geographical impact of the same are highly unevenly spread and transboundary in nature, lending an inherent international aspect to environmental concerns. This leads to the support of finding potential solutions in a multilateral context- through international (IEA) or regional environmental agreements (REA).

The literature surrounding environmental agreements primarily focuses on understanding IEA/REA behaviour, from its classification and formation, to participation and to factors contributing to the compliance of the same (See Barrett 1997, Barett & Stavins 2003). As evidenced in the case of trade agreements, regional environmental

[1] Refer UNFCC (1992)

agreements are more dominant than IEAs.[2] Another important strand of literature deals with the game theory approach of analysing the modeling of an environmental agreement (Finus 2008, Barett 1994). The related fields of analysis that deals with the predominant notions of environmental standards and their effects on competitiveness and emissions, attempt to support or oppose the decision of countries to agree to an REA or IEA. These main studies pertain to a) pollution havens leading to the reluctance of a country to adopt higher environmental standards and b) emissions leakage leading to the skepticism surrounding the efficacy of environmental agreements. The pollution haven hypothesis postulates that the adoption of stricter environmental standards would lead to loss in international competitiveness. This field has received theoretical (Pethig 1976, Copeland & Taylor 1994) and empirical evidence (Ederington & Minier 2003, Ederington et al 2004) in and against its favour (Porter and Van de Linde 1995)[3] and is not unanimously resolved. Emissions leakage suggests that unilateral efforts to reduce local pollution through higher emissions taxes may lead to relocation of polluting industries to countries with lower environmental standards (Fullerton et al 2014, Chua 2003).

Given this backdrop, it becomes essential to understand potential channels that may incentivise countries to adopt better environmental standards, and one of these channels could be the welfare consequences of an environmental agreement. We observe a significant gap in the literature regarding the effects of an REA on the welfare of participating and non-participating countries and addressing this gap is important potential welfare changes might very well prove to be the deciding factor for a country to join or opt out of environmental agreements.

The purpose of this paper is to understand the welfare effects of a regional environmental agreement on the participating countries (or what we refer to as an environmental union, akin to customs union within the trade literature) and on the non-participating countries. The relevant literature pertaining to environmental policy and its coordination between countries essentially deals with the characterisation of optimal (first best and second best) environmental and/or trade policy (See Copeland 1994, Neary 2006) and policy reforms (Turunen-Red & Woodland 2004). The welfare consequences of policy reforms are analyses in a purely unilateral (See Markusen 1975, Copeland 1995, Tsakiris et al 2013) or a fully-cooperative context (See Keen & Kotsogiannis 2012, Kotsogiannis & Woodland 2013, Vlassis 2013). Thus, the middle path of understanding the ramifications of an agreement on a subset of the countries (environmental union) has not been fully explored.

What this paper attempts to study is closest in nature to studies on tariffs in customs unions. Customs unions are a group of countries (often referred to as trade blocs) that have free trade amongst each other and set a common external tariff for trade with the rest of the world. The literature on customs unions dates back to Viner (1950), while the concept was theorised into a general equilibrium model of preferential trading now referred to as the Meade Model (1955). Relevant literature attempts to analyse welfare effects of customs unions on members (Reizman 1979, Bond & Syropoulos 2008) and the rest of the world (Meade 1955). Recent focus has been on tariff adjustments and how welfare improving reforms within the union affect welfare of the rest of the world.

We attempt to study the welfare effects of a group of countries that are bound by a regional environmental agreement under a free trade scenario. The absence of trade policy is to facilitate a clearer identification of the various effects emerging solely from environmental policy. From a practical viewpoint, most countries today are bound by existing trade agreements or WTO trading rules that limit them from changing or increasing their tariffs. For policymakers, this implies the inability to use trade policy to compensate for differences in competitiveness arising from different environmental standards. Thus, it becomes essential to isolate the components of an environmental policy option that affect welfare.

[2] Co-ordination of policies, relatively homogenous nature of fewer regions, enforcement concerns are some of the key reasons of REAs having more success in getting countries to join versus IEAs. Mitchell (2003) surveys Multilateral environmental agreements to number approximately 700 while bilateral agreements number over 1000. Similarly, the database (http://iea.uoregon.edu/) numbers MEAs at 1100 and over 1500 bilateral.

[3] Porter Hypothesis is the main alternative hypothesis which proposes that pollution regulation may increase competitiveness in polluting sectors.

The key finding of the paper is the significance of the terms of trade (magnitude and nature) in the optimal tax and welfare changes of a country. Additionally, a negative relationship between the changes in welfare of the union and non-union countries emerged, via the terms of trade and the market clearing condition. This leads to the conclusion that a welfare improving policy reform within the union might very well be welfare reducing for the non-union countries. Thus, it indicates that the terms of trade might be the key channel of incentives for a country to decide to join a union. While the paper sheds light on the potential channels of incentives for countries to choose to join a union, the limitation is the inability to characterize the nature of these channels.

The paper is structured as follows. Section 2 sets out the model, section 3 then derives the optimal unilateral and cooperative policy, followed by an example to compare the two. Section 4 derives the optimal (country-specific and fully harmonized) pollution policy for the members of the environmental union, followed by examples to compare all the optimal taxes arrived this far. This is followed by arriving at the relationship between the welfare changes of the union and non-union members. Thereafter, a comparison of the changes in welfare of a representative country setting its tax at different optimal levels is done. Finally, a brief discussion is held regarding the impact of size of the union on its optimal policy and change in welfare. Section 5 concludes.

2 The Model

The paper considers a perfectly competitive general equilibrium trade model modified to include pollution and pollution policy, with N large economies, each producing and trading in Q goods.[4] Pollution is a by-product of production and assumed to directly affect consumer welfare, while having no effect on the production capabilities of the firms.[5] Factors of production are assumed to be internationally immobile and inelastically supplied. In the equations that follow, the superscript is used to denote the country.

The vector of world prices is denoted by p and under the assumption of free trade, consumers face the same price vector as producers. Production generates pollutants and the vector of pollutants for country j is denoted by z^j. Pollution is assumed to be trans-boundary and global pollution is thus given by the sum of the pollution across all countries (with i representing the N-vector of 1s and the prime indicates the transpose).[6]

$$k = \sum_{j=1}^{N} i' z^j \tag{1}$$

Consumer preferences are captured by the expenditure function:

$$e^j(U^j, p, k) = min_{x^j}\{p'x^j : \; u^j(x^j, k) \geq U^j\} \tag{2}$$

which represents the minimum cost of achieving the utility level U^j given international prices p and the aggregate pollution level k, where utility depends positively on consumption x and negatively on emission k. The expenditure function is concave and linear homogenous in prices, increasing in utility and assumed to be twice continuously differentiable. Applying Shepard's Lemma, the Hicksian compensated demand vector is represented by e^j_p and the consumer's marginal willingness to pay for pollution abatement in country j is given by e^j_k. Since an increase in the

[4]The modified trade model is similar to Copeland 1994, but uses the N by N large country framework of Turunen-Red & Woodland 2004, Keen & Kotsogiannis 2013.

[5]Refer Copeland 1994, Keen & Kotsogiannis 2012

[6]If pollution is partially trans-boundary, it could imply that only a certain percentage of a country's emissions are transmitted across its borders and affect the rest of the world. If this fraction for country j is denoted by θ^j then global pollution is given by:

$$k = \sum_{j=1}^{N} \left[\left(\theta^j\right) i' z^j \right]$$

level of any pollutant would require an increase in consumption to compensate the consumer for the extra units of pollution, expenditure is increasing in k, implying $e^j_k > 0$.

Each country imposes a sector specific tax on the pollution emitted by producers and this is represented by the vector s^j. The revenue (or GDP) function is then given by:

$$g^j(p, s^j, v^j) = Max_{y,z}\{p^{'}y^j - s^{j'}z^j \,:\; y^j, z^j \epsilon t^j(v^j)\} \tag{3}$$

which states that under perfect competition, each firm maximises profits by choosing a feasible combination of pollution z^j and output y^j of tradeable goods that is consistent with the economy's production possibility frontier summarised by the production technology $t^j(v^j)$, with v^j denoting the vector of endowments. Both the vector of endowments and the production technology are assumed to be fixed. The revenue function is convex, homogenous of degree one in prices and pollution taxes and assumed to be twice continuously differentiable.[7] The function also implies that producers are able to control and abate pollution emissions by altering the production process. From Hotelling's Lemma, price derivatives of the revenue function give the vector of net supply of tradeable goods $y^j = g^j_p$. The envelope property also implies that $z^j = -g^j_s$, i.e. the vector of pollutants equals the marginal abatement costs. Totally differentiating z^j gives :

$$dz^j = -(g^j_{ss}ds^j + g^j_{sp}dp^j) \tag{4}$$

It then follows from 1 that:

$$k = -\sum_{j=1}^{N} i^{'}g^j_s \tag{5}$$

Thus, change in global pollution is given by:

$$dk = -\sum_{j=1}^{N} i^{'}(g^j_{ss}ds^j + g^j_{sp}dp) = -\sum_{j=1}^{N}(i^{'}g^j_{ss}ds^j) - \sum_{j=1}^{N}(i^{'}g^j_{sp}dp) \tag{6}$$

The above equation indicates that changes in global pollution levels are dependent on the sensitivity of the production sector to changes in pollution taxes and prices. Pollution taxes affect the pollution levels directly via the $\left(\sum_{j=1}^{N}(i^{'}g^j_{ss}ds^j)\right)$ term and indirectly by affecting price levels which in turn affect the production and hence the global pollution.

Equilibrium conditions:

It is assumed that the pollution tax revenues are returned to the consumer in a lump-sum manner. Thus, the economy's aggregate budget constraint is given by:

$$e^j(U^j, p, k) = g^j(p, s^j) + s^{j'}z^j \tag{7}$$

The market clearing condition requires that net imports equal zero, where each country's imports is: $m^j = e^j_p - g^j_p$ Thus the market clearing condition is:

$$\sum_{j=1}^{N} m^j = \sum_{j=1}^{N}\{e^j_p - g^j_p\} = 0 \tag{8}$$

In other words, the sum of excess demands across the world should be equal to zero.

[7] For detailed understanding of the revenue function refer Dixit & Norman (1980)

The equilibrium conditions are described by equations (7) and (8). Fully differentiating the two conditions gives the optimal pollution policy.

3 Optimal Pollution Policy

Fully differentiating the budget constraint (7) would yield the expression for changes in welfare and the factors that affect the same. Perturbation of the market clearing condition (8) would reveal the relationship between pollution policy and price levels. Thereafter, maximising these equations under fully cooperative or unilateral conditions would yield the optimal pollution policy.

3.1 Unilateral Optimal Policy

Perturbation of equation (8) reveals the effect of pollution policy changes on international prices. [8]

$$\Lambda dp = \sum_{j=1}^{N} \left\{ \left[g_{ps}^{j'} + \left(\sum_{j=1}^{N} e_{pk}^{j} \right) i' g_{ss}^{j} \right] ds^{j} \right\} \tag{9}$$

where

$$\Lambda = \sum_{j=1}^{N} \left[e_{pp}^{j'} - g_{pp}^{j'} - \left(\sum_{j=1}^{N} e_{pk}^{j} \right) i' g_{sp}^{j} \right] \tag{10}$$

The matrix Λ is assumed to be of full rank and invertible. Thus:

$$dp = \Lambda^{-1} \sum_{j=1}^{N} \left\{ \left[g_{ps}^{j'} + \left(\sum_{j=1}^{N} e_{pk}^{j} \right) i' g_{ss}^{j} \right] ds^{j} \right\} \tag{11}$$

Thus world prices are affected by:

- The net substitution matrix, or the impact of changes in prices on net imports $\left(e_{pp}^{j'} - g_{pp}^{j'} \right) dp$
- The impact of changes in pollution tax policy on each country's production levels $\left(g_{ps}^{j'} ds^{j} \right)$ and emissions levels $\left(g_{ss}^{j'} ds^{j} \right)$ weighted with the impact of global pollution on compensated demands $\left(\sum_{j=1}^{N} e_{pk}^{j} \right)$
- The impact of prices on production emissions $\left(g_{sp}^{j'} dp \right)$ weighted by the effect of pollution on compensated demands $\left(\sum_{j=1}^{N} e_{pk}^{j} \right)$

The above equation is similar in nature to equation (5) of Tsakiris et al (2013) which expresses change in prices as a function of change in both trade and environmental policies of a two country case. The points of difference arise from the presence of free trade and thus no trade policy option in our case.

Now, to evaluate the impact of pollution policy on welfare, we fully differentiate the budget constraint equation (7)

$$e_{u}^{j} du^{j} = \left[-m^{j'} - s^{j'} g_{sp}^{j} + e_{k}^{j} \left(\sum_{j=1}^{N} i' g_{sp}^{j} \right) \right] dp - s^{j'} g_{ss}^{j} ds^{j} + e_{k}^{j} \sum_{j=1}^{N} \left(i' g_{ss}^{j} ds^{j} \right) \tag{12}$$

[8] Each country's income effects are assumed to be attached only to the numeraire good thus making the term $e_{pu}^{j} = 0$.

Equation (12) gives the impact of changes in world prices and pollution policy of country j on the welfare of country j.[9] This equation supports the welfare equation found in Vlassis (2013).

Welfare function in each country is affected by:

- Terms of trade effect $\left(-m^j\right) dp$. As world prices increase, terms of trade for a net importing country worsen and thus reduce its welfare. The reverse holds true for a net exporting country.
- Impact of world prices on a country's pollution tax revenue $\left(-s^{j'} g^j_{sp} dp\right)$. As prices increase, production increases leading to an increase in emissions and thus higher pollution tax revenue.[10]
- Impact of prices on global emissions weighted by the individual country's marginal willingness to pay for its abatement $\left(e^j_k \sum_{j=1}^{N} \left(i' g^j_{sp}\right) dp\right)$. As prices increase, production and emissions increase, leading to consumers increasing their consumption of goods to compensate for the added pollution.
- Impact of pollution policy on domestic emissions weighted by the environmental tax$\left(s^{j'} g^j_{ss} ds^j\right)$. Increase in pollution tax reduces domestic emissions but may increase emissions elsewhere (pollution haven hypothesis).
- Impact of pollution policy changes on global emissions weighted by the marginal damage to domestic consumers; As pollution tax increases, domestic emissions reduce but foreign emissions may increase or decrease.

In this paper, the single policy option available is the environmental policy. Thus, re-writing the welfare function of country j to reflect it (the welfare) as a function of only pollution policy changes. This is done so by substituting for dp from equation 11 in equation 12 :

$$
\begin{aligned}
e^j_u du^j = \quad & -m^j \sum_{j=1}^{N} \left(\mu^j ds^j\right) \\
& -s^{j'} g^j_{sp} \sum_{j=1}^{N} \left(\mu^j ds^j\right) - s^{j'} g^j_{ss} ds^j \\
& +e^j_k \sum_{j=1}^{N} \left\{ \left[i' g^j_{ss} + i' g^j_{sp} \left(\sum_{j=1}^{N} \mu^j \right) \right] ds^j \right\}
\end{aligned}
\tag{13}
$$

where

$$
\mu^j = \Lambda^{-1} \left[g^j_{ps} + \left(\sum_{j=1}^{N} e^j_{pk} \right) i' g^j_{ss} \right]
$$

The above equation (13) gives the welfare of a country in terms of the single policy option- environmental policy. The first line of the equation expands on the terms of trade effect; the second line gives the impact of pollution tax on emissions $\left(s^{j'} g^j_{ss} ds^j\right)$ and via production on pollution tax revenue $\left(s^{j'} g^j_{sp} \sum_{j=1}^{N} \left\{\mu^j ds^j\right\}\right)$. The last line shows the impact of pollution policy on the marginal damage faced by consumers from the ensuing changes in pollution levels.

[9] e^j_u is the reciprocal of the marginal utility of income, $e^j_u du^j$ represents the change in utility in terms of the numeraire good and may be thought of as the change in real income of country j. Refer Panagariya (1997)

[10] The magnitude of this term depends on the pollution intensity of the good and the initial tax levels.

Global welfare can be derived by adding the individual welfare functions for all the N countries and combining that with the market clearing condition from equation (8) giving:

$$\sum_{j=1}^{N} e_u^j du^j = \begin{array}{l} -\sum_{j=1}^{N} \left\{ s^{j'} \left(g_{ss}^j + g_{sp}^j \left(\sum_{j=1}^{N} \mu^j \right) \right) ds^j \right\} \\ + \sum_{j=1}^{N} \left\{ e_k^j i' \sum_{j=1}^{N} \left\{ \left(g_{ss}^j + g_{sp}^j \left(\sum_{j=1}^{N} \mu^j \right) \right) ds^j \right\} \right\} \end{array} \tag{14}$$

Thus global welfare is represented in terms of pollution policy changes across countries. Particularly, it accounts for the impact of pollution policy on emissions and its weighted effect with the consumer marginal willingness to pay and with individual pollution taxes.

In case of policy that is set non-cooperatively, it would mean each country sets its tax unilaterally to maximise its own welfare while assuming the policy levels of all other countries as fixed at an arbitrary level. This gives unilateral optimal environmental policy as:

$$\begin{aligned} s^{uni'} &= -m^j \left(g_{sp}^j\right)^{-1} \\ &+ \left(e_k^j - s^{j'}\right) \left(i' g_{ss}^j\right) \left[g_{sp}^j\right]^{-1} \\ &+ e_k^j \left(\sum_{j=1}^{N} i' g_{sp}^j \right) \left(g_{sp}^j\right)^{-1} \end{aligned} \tag{15}$$

Thus, optimal tax of country j, (set non cooperatively) depends on:

- Terms of Trade weighted by the pollution intensity of country j; reflected by the term $\left(m^j \left(g_{sp}^j\right)^{-1}\right)$. A pollution intensive net importing country would have a higher optimal tax than a pollution intensive net exporting country, ceteris paribus.
- Difference between the consumer's marginal willingness to pay (for pollution abatement) and the environmental tax weighted by the policy induced emissions $\left(\left(e_k^j - s^{j'}\right) \left(i' g_{ss}^j\right) \left[g_{sp}^j\right]^{-1}\right)$.
- Impact of (environmental policy induced) change in prices on global emissions weighted by the consumer's marginal willingness to pay for abatement $\left(e_k^j \left(\sum_{j=1}^{N} i' g_{sp}^j \right) \left(g_{sp}^j\right)^{-1} \right)$.

This result is consistent with the non-cooperative optimal policy set out in Keen & Kotsogiannis (2012). They extend Markusen's (1975) single country optimal taxes to get the N country counterpart which is comparable to our equation (15). In both the cases, the unilaterally set optimal tax includes the terms of trade effect, the marginal damage term and the impact of policy induced price changes on global emissions. In Keen & Kotsogiannis, the price changes ensue from changes in trade tariffs, while in our case, changes in pollution policy induce price changes that affect global emissions via production. Moreover, our result has additional variables that correspond to the impact of environmental policy on emissions $\left(g_{ss}^j\right)$ and production $\left(g_{ps}^j\right)$. Intuitively, the presence of these terms in our case arise from the use of a single policy option to address several distortions at the same time[11].

[11] Refer Markusen 1975 where the author attempts to analyse corrective taxation in the case of a single policy instrument to deal with several distortions simultaneously

The unilateral optimal tax is also similar in nature to the Nash equilibrium carbon permit price set out in Copeland's (1995) paper. The non-cooperative equilibrium carbon permit price equals marginal willingness to pay for pollution abatement and an indirect terms of trade effect. The key difference between the latter's result and ours is the impact of policy induced price changes on global emissions. This term exists in our optimal tax because of the absence of trade policy to target trade related distortions.

Comparing the equation (15) with that of a 2 country-2 good case laid out in Tsakiris et al (2013), certain similarities and differences are notable due to the latter having two policy options vis-a-vis our single environmental policy. In both cases, the unilateral optimal tax depends on the difference of the tax from the marginal willingness to pay $\left(e_k^j - s^{j'}\right)$ and the terms of trade effect (m^j). The key point of difference between the two results is the inclusion of the term representing the impact of prices on global emissions $\left(\sum_{j=1}^{N} i' g_{sp}^j\right)$ in our case. Intuitively, the reasoning follows that in the absence of trade tariffs on polluting imports that can account for the increased emissions caused by production in foreign countries; optimal environmental tax now has to include the impact of (environmental policy induced) price changes on global emissions weighted by the marginal damage faced by consumers of country j.

3.2 Cooperative Optimal Policy

If all countries decided to set their policy in a cooperative manner, it would imply choosing an optimal tax level that maximises global welfare. To derive that, equation (14) can be re-written as:

$$\sum_{j=1}^{N} e_u^j du^j = \sum_{j=1}^{N} \left\{ \left[\left(\sum_{j=1}^{N} e_k^j i' \right) - s^{j'} \right] \delta^j \right\} \tag{16}$$

where $\delta^j = \left[g_{ss}^j + g_{sp}^j \left(\sum_{j=1}^{N} \mu^j \right) \right] ds^j$

Maximising equation (16) means that as $\delta \neq 0$ global welfare is maximised when

$$s^{coop} = \left(\sum_{j=1}^{N} e_k^j i \right) \tag{17}$$

Thus, to maximise aggregate welfare in a cooperative policy setting has two implications. First, each country sets the same level of tax. Secondly, the tax is set equal to the cumulative (global) marginal damage caused by an additional unit of emission. Since the marginal damage from emissions is the same irrespective of the sector that generates the emissions, each country sets the same pollution tax across all the sectors [12]. The above result is fully consistent with the related literature. Our result mirrors the free trade case in the Keen & Kotsogiannis (2012) paper (and reconfirmed in Vlassis 2013) where the absence of trade tariffs led to the vector of carbon taxes in each country to be set at first best Pigouvian levels. In the other case, the authors include a variable to capture the income neediness of a country that allows countries, within the cooperative framework, to set different levels of tax. However, the optimal environmental tax is again found to be uniformly set across all countries in case international lump sum transfers are allowed.

[12] See proposition 1 of Keen & Kotsogiannis (2012)

This result is also found to be consistent with models based on different mechanisms of climate change influences. As in the case of Kotsogiannis & Woodland (2013) where emissions affect the production and not utility, the pareto efficiency calls for each country to set the same carbon tax in each sector to equate the marginal cost of an extra unit of emission with the marginal global damage (to production revenue) from this extra unit of emission.

3.3 Comparing the Cooperative and the Non-cooperative Optimal Tax

To analyse the above, a simple 3 by 3 version of the model is considered with the following assumptions:

- Assume a 3 country and 3 good case, with good 1 being the least polluting; good 2 is moderately polluting and good 3 is most polluting.
- Each country produces all the goods but specialises in only 1 good. Thus, country 1 specialises in good 1 and imports good 2 and 3; country 2 specialises in good 2 and imports goods 1 and 3 and so on.
- There is free trade, thus no import taxes
- All three goods are assumed to be close substitutes
- Assume global pollution does not have an impact on compensated demand, thus $e_{pk} = 0$

Cooperative tax would be: $s^{coop} = e_k^1 + e_k^2 + e_k^3$

Let country 1 set its tax at unilateral optimal level at:

$$s^{uni} = \begin{array}{c} -m^1\mu^1\left(g_{ss}^1 + g_{sp}^1\mu^1\right)^{-1} \\ +e_k^1 \\ +e_k^1\left(g_{sp}^2 + g_{sp}^3\right)\mu^1\left(g_{ss}^1 + g_{sp}^1\mu^1\right)^{-1} \end{array}$$

Another interpretation of Λ or the substitution matrix is that it is the change in the compensated demand from each country in response to a change in the prices. As prices increase, compensated demand falls, thus making $\Lambda < 0$.

- The variable g_{ps}^1 measures the impact of a change in pollution tax of country 1 on its production levels. This variable is negative because as pollution tax increases, cost of production increases, thus reducing the production levels of country 1. This makes the variable $\mu^1 > 0$.
- The variable g_{ss}^1 measures the impact of a change in country 1's pollution policy on it emission levels. As s^1 increases, production reduces and emissions reduce, thus leading to this variable being positive. However, if the variable in question was g_{ss}^{12} then an increase in s^{2}might lead to an increase in emissions of country 1, making this variable negative.
- The variables g_{sp}^1, g_{sp}^2 and g_{sp}^3 are negative as an increase in prices levels (of any good) would lead to an increased production of that good in all the countries and thus increased emissions in all the countries.

Condition 1: The magnitude of the impact of pollution policy on emissions is greater than that of prices on emissions weighted by the substitution matrix, $\mid g_{ss}^1 \mid > \mid g_{sp}^1\mu^1 \mid$

Condition 2: A country's terms of trade is greater than the impact of prices on the rest of the world's emissions, weighted by the marginal damage of the home country $\mid m^1 \mid > \mid e_k^1\left(g_{sp}^2 + g_{sp}^3\right) \mid$

a) If the country is a net importer, and condition 1 is fulfilled, the unilateral pollution tax is less than the marginal damage to the consumers of that country. This implies the unilateral optimal tax is lower than the fully cooperative tax. Thus in this case, a net importing country would not prefer to enter into an environmental agreement!

b) If the country is a net exporter and condition 1 and 2 are fulfilled, then the non cooperatively set environmental tax is greater than the marginal damage caused to the consumers of the country. Depending on the magnitude of the marginal willingness to pay (or the marginal damage of the other countries), the net exporter country might find that the optimal unilateral tax is higher than a fully cooperative tax.

Thus the terms of trade and the magnitude of the same are key factors in the comparison of optimal unilateral and cooperative taxes.

4 Case of an Environmental Union

If a set of countries enter into an environmental agreement and thus decide to set their pollution policy cooperatively, what would be the impact of this environmental union on the remaining countries? The following section attempts to study this impact.

Of the N countries, let a subset of countries $h \in [1, M]$ sign an environmental agreement. Let the remaining countries be denoted by superscript $f \in [M, N]$where $[1, M] \cup [M, N] = [1, N]$

Welfare of the coordinating union countries is arrived at by summing the individual welfare functions for the union countries to get:

$$\sum_{h=1}^{M} e_u^h du^h = \begin{array}{l} \sum_{h=1}^{M} \left\{ (-m^h) \sum_{j=1}^{N} \left(\mu^j ds^j \right) \right\} \\ -\sum_{h=1}^{M} \left\{ s^{h'} \left(g_{ss}^h ds^h + g_{sp}^h \sum_{j=1}^{N} \left(\mu^j ds^j \right) \right) \right\} \\ +\sum_{h=1}^{M} \left\{ e_k^h i' \sum_{j=1}^{N} \left\{ \left(g_{ss}^j + g_{sp}^j \sum_{j=1}^{N} \mu^j \right) ds^j \right\} \right\} \end{array} \tag{18}$$

Thus the union's welfare depends on its terms of trade $\left(\sum_{h=1}^{M} \left\{ (-m^h) \sum_{j=1}^{N} \left(\mu^j ds^j \right) \right\} \right)$; cumulative impact of policy on emissions (direct and through production changes) $\left(\sum_{h=1}^{M} \left\{ s^{h'} \left(g_{ss}^h ds^h + g_{sp}^h \sum_{j=1}^{N} \left(\mu^j ds^j \right) \right) \right\} \right)$; cumulative impact of policy on emissions weighted by the marginal damage (or marginal willingness to pay) of the union.

4.1 Optimal Union Pollution Policy

Maximising the welfare function of the union (18) yields the optimal union pollution policy.

$$\sum_{h=1}^{M} \left\{ s^{h'} \left(g_{ss}^h + g_{sp}^h \theta \right) \right\} = \begin{array}{c} \left(\sum_{h=1}^{M} (-m^h) \right) \theta \\ + \left(\sum_{h=1}^{M} e_k^h i' \right) \left\{ \sum_{h=1}^{M} \left(g_{ss}^h + g_{sp}^h \theta \right) \right\} \end{array}$$

where $\theta = \left(\sum_{h=1}^{M} \mu^h \right) = \Lambda^{-1} \sum_{h=1}^{M} \left\{ \left[g_{ps}^h + \left(\sum_{h=1}^{N} e_{pk}^h \right) \left(i' g_{ss}^h \right) \right] \right\}$

The above gives two options for the optimal tax- if countries decide to set the same tax within the union or if the countries coordinate and set different levels of tax, while ensuring the union welfare is maximised.

If the union decides to set different taxes for each of the members, then optimality dictates that each country would set its taxes according to:

$$s^{l-union'} = \begin{array}{c} \left(\sum_{h=1}^{M}(-m^h)\right)\theta\left(g_{ss}^l + g_{sp}^l\theta\right)^{-1} \\ -\sum_{h=1,h\neq l}^{M}\left\{s^{h'}\left(g_{ss}^h + g_{sp}^h\theta\right)\right\}\left(g_{ss}^l + g_{sp}^l\theta\right)^{-1} \\ +\left(\sum_{h=1}^{M}e_k^h i'\right)\left\{\sum_{h=1}^{M}\left(g_{ss}^h + g_{sp}^h\theta\right)\right\}\left(g_{ss}^l + g_{sp}^l\theta\right)^{-1} \end{array} \tag{19}$$

Thus the optimal union tax for country l is defined by:

- Terms of trade of the entire union, weighted by the effect of tax and prices on emissions. $\left[\left(\sum_{h=1}^{M}(-m^h)\right)\theta\left(g_{ss}^l + g_{sp}^l\theta\right)^{-1}\right]$.
- Environmental tax of other union members weighted by the effect of their (other union countries) tax and prices on their emissions. $\left[\sum_{h=1,h\neq l}^{M}\left\{s^{h'}\left(g_{ss}^h + g_{sp}^h\theta\right)\right\}\left(g_{ss}^l + g_{sp}^l\theta\right)^{-1}\right]$. Intuitively, the higher the tax set by other union members, the lower the tax that country l can set. Thus, if the other union members take on a higher burden of a stringent policy standard, country l can afford to set comparatively lower environmental standards.
- The union's aggregate marginal willingness to pay for pollution abatement weighted by the sum of the union's impact of prices and taxes on its emissions. $\left[\left(\sum_{h=1}^{M}e_k^h i'\right)\left\{\sum_{h=1}^{M}\left(g_{ss}^h + g_{sp}^h\theta\right)\right\}\left(g_{ss}^l + g_{sp}^l\theta\right)^{-1}\right]$. The greater the number of members of the union, the greater is the aggregate marginal willingness to pay for pollution abatement.

In the above case where union members co-ordinate their policies and set country-specific taxes, the key difference between their taxes arises from the $\left[g_{ss}^l + g_{sp}^l\theta\right]$ term. Thus the direct and indirect (through change in prices and production) impact of pollution tax on a country's emissions decide the difference in the magnitude of the tax set by each member.

In the case of perfect harmonization within the union, the optimal tax will be given by:

$$s^{h-union'} = \begin{array}{c} \sum_{h=1}^{M}(-m^h)\theta\left[\sum_{h=1}^{M}\left(g_{ss}^h + g_{sp}^h\theta\right)\right]^{-1} \\ +\left(\sum_{h=1}^{M}e_k^h i'\right) \end{array} \tag{20}$$

In this case, it is clear that a uniform tax accounts for two key terms, the aggregate marginal willingness to pay $\left(\sum_{h=1}^{M}e_k^h i'\right)$ and the union terms of trade weighted by the cumulative impact of policy on emissions $\left(\sum_{h=1}^{M}(-m^h)\theta\left[\sum_{h=1}^{M}\left(g_{ss}^h + g_{sp}^h\theta\right)\right]^{-1}\right)$. If the union was a net importer (exporter), then an improvement it's terms of trade would perhaps lead to a lower (higher) environmental tax. The precise effect cannot be ascertained due to the unknown sign of the cumulative (direct and indirect) impact of policy on union emissions. A greater number of members implies a higher aggregate marginal willingness to pay and thus the tendency for a higher union optimal tax. A further discussion of the union size follows later.

4.2 Optimal Non-union pollution policy

Non Union Welfare

The welfare of a non-union country is the same as the welfare equation set out in equation 13. The optimal pollution tax is the same as the unilaterally set tax given in equation 15

4.3 Comparing Optimal Taxes

Section 3.3 compares the optimal cooperative and unilateral policies. This section aims to compare the latter with the union's optimal tax. The same assumptions are made here with the addition of the assumption that countries 1 and 2 form an environmental union.

- **Part A:** Fully cooperative tax $[s^{coop}]$ and Union's fully harmonized optimal tax $\left[s^{h-union'}\right]$.

This comparison essentially shows the difference in case of complete cooperation and partial cooperation within countries. The magnitude of the union's terms of trade is a key factor that decides how much higher (than the cumulative marginal damage), should their pollution tax be set. Whether this difference reflected in the term $\left[(m^1+m^2)\theta\left[\left(g^1_{ss}+g^1_{sp}\theta+g^2_{ss}+g^2_{sp}\theta\right)\right]^{-1}\right]$makes the union tax equal to or greater than the fully cooperative tax requires further assumptions. As long as the union's weighted terms of trade is less than the marginal willingness to pay (for pollution abatement) of the non-union, the union tax will be less than the fully cooperative tax.

Part B: Unilateral optimal policy $\left(s^{uni'}\right)$ and harmonized union tax $\left(s^{h-union'}\right)$

This comparison is between a country's environmental tax if it joins the union or stays out of it. This depends on whether the country in question is a net importer/exporter and whether the union is a net importer/exporter.

If country 1 (net importer) is part of a net exporting union, then the country has to set its optimal tax higher than the cumulative union marginal damage; implying that it has to set its tax at a higher level if it joins the union.

This leads to the question of why would a net importer country join a union if the union is a net exporter since joining it implies increasing its environmental standards. The possible incentive for joining the union and offsetting the increased environmental costs arises from the potential increase in trade (trade creation effect) between country 1 and the union. This term is what causes the main difference between the environmental tax and the cumulative marginal damage (or cumulative marginal willingness to pay for abatement) of the union. This is reflected in $\left[(m^1+m^2)\theta\left[\left(g^1_{ss}+g^1_{sp}\theta+g^2_{ss}+g^2_{sp}\theta\right)\right]^{-1}\right]$. One of the shortcomings of this analysis is the inability to dissect this term to understand the trade creation (diversion) effect and thus the incentive for the country to join (not join) the union. Thus the existing model helps to identify the potential channel of incentives for countries to join a union; but the exact characterisation of the incentives would require a modified version of the model.

- **Part C:** Union optimal tax when fully harmonized $\left[s^{h-union'}\right]$ and when set differently $\left[s^{l-union'}\right]$

The most obvious point of difference between these two taxes is the term that accounts for the pollution tax set by other union members. The inclusion of this term in $s^{l-union'}$allows the country to potentially set its tax lower than the fully harmonized union tax. Intuitively, if other countries impose strict environmental policies, country l can impose lower standards and still maximise the welfare of the union as a whole. To illustrate this and find conditions under which this might hold, we use the same assumptions set out at the start of the section.

Assuming that the value of the direct policy effect on emissions is greater than that of the indirect effects on emissions (weighted by the effect of policy on production) for all the union members , i.e.$| g^1_{ss} |>| g^1_{sp}\theta |and| g^2_{ss} |>| g^2_{sp}\theta |$, then for a net importing union $\left[(m^1 + m^2) > 0\right]$, the harmonized tax is set lower than the cumulative marginal damage of the union.

For the differently set tax, if absolute value of the two negative terms is greater than the value of the positive marginal damage term, then it implies the tax for the country would be a subsidy. Intuitively, if the other union members set a tax high enough that overshadows the effects of the cumulative marginal damage, then country l can afford to set an environmental subsidy instead of a positive environmental tax.

However, the same cannot be concluded for the $s^{l-union}$ which has two terms that raise the pollution tax but one term which reduces the optimal tax. This latter effect is due to the inclusion of the optimal taxes of other union members. If other union members (in this case, country 2) decide to lower their taxes, then to ensure maximisation of union welfare would require country 1 to raise its environmental tax and vice versa. This ability to coordinate and set different levels of tax within the union helps to account for individual country differences (production levels, pollution intensities).

Summary of non-domestic factors affecting Optimal Policy

Unilateral	***Cooperative***
-it depends on its own terms-of-trade	-No terms-of-trade
-own country's marginal damage from pollution	-aggregate marginal damage of pollution
Union	***Union Harmonized***
-participating countries terms-of-trade	-participating countries terms-of-trade
-other participating countries' environmental tax	-participating countries marginal damage of pollution
–participating countries marginal damage of pollution	

The above table shows the different factors (apart from the country's own variables) that affect its optimal tax. The fully cooperative policy has the least informational requirements while all the other cases have more complex requirements. This leads to the future scope of research of whether a union (REA) is the first step in achieving full policy cooperation (IEA).

4.4 Welfare of Union and Non Union Members

This section aims to understand the relationship between the welfare functions of union and non union members. By doing so, it would provide the base to understanding how potential tax reforms might affect the welfares.

Market clearing condition from equation 8 gives:

$$-\sum_{h=1}^{M} m^h = \sum_{f=M}^{N} m^f$$

Combining the market clearing equation with the union welfare and the sum of the terms of trade of the non-union countries gives:

$$\begin{aligned}\sum_{h=1}^{M} e_u^h du^h = \quad & -\sum_{f=M}^{N} e_u^f du^f \\ & -\sum_{f=N}^{M} \left\{ s^{f'} \left(g_{ss}^f ds^f + g_{sp}^f \sum_{j=1}^{N} \left(\mu^j ds^j\right) \right) \right\} - \sum_{h=1}^{M} \left\{ s^{h'} \left(g_{ss}^h ds^h + g_{sp}^h \sum_{j=1}^{N} \left(\mu^j ds^j\right) \right) \right\} \\ & + \sum_{f=M}^{N} \left\{ e_k^f i' \sum_{j=1}^{N} \left\{ \left(g_{ss}^j + g_{sp}^j \sum_{j=1}^{N} \mu^j \right) ds^j \right\} \right\} + \sum_{h=1}^{M} \left\{ e_k^h i' \sum_{j=1}^{N} \left\{ \left(g_{ss}^j + g_{sp}^j \sum_{j=1}^{N} \mu^j \right) ds^j \right\} \right\}\end{aligned}$$

The above equation shows a negative relation between changes in union welfare and changes in non-partipating countries. This implies that if the union undertakes a welfare improving tax reform, it might end up being welfare reducing for the non-union members.[13] This is another channel that gives a potential incentive for non participating countries to join the union and benefit from the welfare improving effects of union policy changes.

Thus in conclusion, when the tax of a representative country is set equal to one of the above optimal tax levels, the welfare changes of this country are dependent on various external (non-domestic) factors. While for all the cases, welfare changes depend on the country's terms of trade and its own marginal willingness to pay, each of the cases gives rise to further factors. For the unilateral tax case, the welfare changes depend on the policy impacts of the rest of the world on their emissions. In addition to this, for the fully cooperative case, the welfare changes also depend on the marginal damage of the rest of the world.

For the union case, (country-specific and harmonized) the change in welfare becomes dependent on the union's terms of trade. Thus, any improvement in the union's terms of trade (even if it implies worsening of the country's terms of trade) would potentially result in a positive impact on welfare. This result corroborates the case for trade effects (trade creation/diversion) being a channel of incentive for countries to join the union. In addition to this effect, the cumulative marginal damage of the union affects the welfare changes of the representative country. Furthermore, both cases show the dependence of the welfare changes on the rest of the world's policy effects on their emissions. For the country-specific tax case, there is an additional term that affects the welfare changes (in a positive manner), which is the term representing the other union members' tax levels. Higher taxes set by the union members has a positive impact on the change in welfare of country j.

Consider the case, where the optimal tax (lets say, unilaterally set) is higher than what the policymakers of the country are willing to impose. In this case, joining a union might benefit the country as it can afford to set a lower tax (if the other union members set higher tax levels) and still fulfill its environmental policy-related responsibility. Thus the inclusion of the taxes set by other union members in the welfare change equation generates another potential source of incentive for a country to join a union.

[13]This result is echoed in the 3 by 3 example set out in Vlassis 2013

4.5 Policy Reform

In order to characterize the nature of the policy for the reform to be welfare improving we consider a special case, imposing some restrictive assumptions: $e_{pk} = 0$, $e_{pp} = 0$ and $g_p = -\alpha g_s$ (Keen and Kotsogiannis, 2014)

Also assume that, at the initial equilibrium, $s^j = 0$

In this case the policy has an effect only through the terms of trade channel as given below:

$$\sum_{h=1}^{M} e_u^h du^h = -\left(\sum_{f=M+1}^{N} m^f\right)' \left(\sum_{j=1}^{N} g_{pp}^j\right)^{-1} \left(\sum_{j=1}^{N} g_{ss}^j ds^j\right)$$

If the non participating countries are passive, a reform which will decrease the trade with the non participating countries, such as:

$$ds^h = -\kappa \sum_{f=M+1}^{N} m^f \text{ with } \kappa \text{ being a positive scalar}$$

would be Pareto improving for the participating and welfare decreasing for the non participating countries

$$\sum_{h=1}^{M} e_u^h du^h = \kappa \left(\sum_{f=M+1}^{N} m^f\right)' \left(\sum_{j=1}^{N} g_{pp}^j\right)^{-1} \left(\sum_{j=1}^{M} g_{ss}^j\right) \left(\sum_{f=M+1}^{N} m^f\right) > 0$$

since g_{pp} and g_{ss} are positive definite.

Hence the Pareto improving reform hinges on "terms-of-trade-driven trade creation and trade diversion effects". Thus an environmental union can set a tax reform that improves its own welfare while reducing the welfare of the non-union countries. This stems from the terms of trade effect and is thus the key channel of incentive that could induce non-participating countries to join the union.

4.6 Size of the Environmental Union

While a smaller union requires the inclusion of fewer country variables thus leading to a lower optimal tax, a larger union might have stronger trade effects. The following section aims to shed light on the significance of the size of the environmental union. The impact of size will first be analysed with respect to the optimal union tax (considering the fully harmonized case) and then with respect to the change in welfare.

The optimal union tax (harmonized case) depends on the terms of trade of the union and the cumulative marginal damage of the union.

$$s^{h-union'} = \sum_{h=1}^{M}(-m^h)\theta \left[\sum_{h=1}^{M} \left(g_{ss}^h + g_{sp}^h\theta\right)\right]^{-1} + \left(\sum_{h=1}^{M} e_k^h i'\right)$$

Assuming that the absolute value of the direct effect of policy on emissions is greater than the absolute value of the indirect effect weighted by the policy effect on production, that is, $\mid g_{ss}^h \mid > \mid g_{sp}^h\theta \mid$, making the term $\left(g_{ss}^h + g_{sp}^h\theta\right) > 0$. Additionally, assuming $\theta > 0$, implies that as the number of countries within the union increase, $\sum_{h=1}^{M}\left(g_{ss}^h + g_{sp}^h\theta\right)$ and the term θ increase. As is evident in the above equation, as size of the union increases, the cumulative marginal damage, or rather, the cumulative marginal willingness to pay for pollution abatement of the union increases which tends to raise optimal tax. However, the exact impact of an increase in the number of members on the optimal tax is not as straightforward due to the effect of the terms of trade of the union $\left[\sum_{h=1}^{M}(-m^h)\right]$.

As members increase, the union's terms of trade change depending on the initial composition of the members and the trading status of the joining members. Additionally, as the size of the union increases with a balanced mix of importer and exporter countries, the absolute value of the terms of trade will start falling. Consider the case where the new joining members lead to the union being a net exporter (irrespective of the initial net importer/exporter status), then the increase in size leads to a clear increase in the optimal union tax. However, as the size of the union keeps increasing, the magnitude of the terms of trade will start diminishing which will lower the optimal tax.

The model helps to identify the channels through which union size impacts (positively or negatively) the union optimal policy and the change in its welfare. However the final effect of the size on the optimal tax and welfare cannot be precisely ascertained by this model. This is because, the variable of terms of trade– not only the sign (net importer/exporter) but also the magnitude changes with the inclusion of new countries. This affects the optimal union tax which in turn affects the change in welfare of the union.

5 Conclusion

The paper uses a modified N-country Q-goods general equilibrium framework and arrives at optimal environmental policies- unilateral, fully cooperative and environmental union. A country's terms of trade- both the nature and magnitude have emerged to be the key factors that affect optimal policy, union size and welfare levels. These terms of trade are what lead to trade creation and trade diversion effects, which are the main channel of incentives for countries to join an environmental union. The potential gains from increased trade may offset the increased costs of higher environmental taxes within a union. The union can fully harmonise tax levels or choose to set different levels of tax. In case of the latter, it allows for individual members to even set lower taxes and still benefit from increased overall environmental standards of the union.

A key finding of this paper is the negative relationship between the welfare changes of the union and that of the non-participating countries. This negative relationship stems from the market clearing condition and allows for the union to impose tax reforms that are pareto improving for itself but welfare reducing for all the non-participating countries. This forms another potential avenue to entice non-participating countries to join the union.

The paper elaborates on the factors that affect union size and finds that again, the terms of trade of a joining country and the nature of the union's terms of trade are key in determining whether optimal tax and changes in welfare increase or decrease. Additionally a country's marginal willingness to pay for pollution abatement is an essential variable in its optimal policy and welfare.

The paper identifies the channel of incentives for signing a regional environmental agreement, but is limited in characterising the same.

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