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Abstract

We analyse the welfare effects of environmental policy arising from the formation of an international environmental agreement on the participating and non-participating countries and thus shed light on the potential incentives for a country to join such an agreement. Within a N-country Q-goods general equilibrium framework under free-trade conditions, we consider unilateral and cooperative policy settings and, within the latter, country-specific and fully harmonized policies within the agreement. A key result in the paper is the emergence of a negative relationship, arising from terms of trade effects, between the welfare changes of the participating and non-participating countries following the formation of the agreement.

Keywords: International Environmental Agreements; Environmental taxation; International trade; Pareto efficiency; Pareto improving reforms; Climate change.

JEL classification: Q56; H23; F18.

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1 Introduction

Climate change and the trans-boundary nature of environmental pollutants have drawn the attention of academics and policymakers to the interaction between international trade and the environment and to the importance of internationally coordinated actions in addressing environmental concerns. Since the United Nations Conference on the Human Environment in 1972, environmental policy efforts globally have been geared towards finding potential solutions in a multilateral context – through international (IEA) or regional environmental agreements (REA).[1]

The extant theoretical literature suggests that countries may not be willing to restrict environmental policy in order to avoid free-riding behaviour and/or – as reflected by the pollution haven hypothesis – due to fears of a loss of competitiveness. A key rationale behind environmental agreements and coordinated actions is to limit such free-riding incentives (Baylis et al., 2014; Chua, 2003).Against this background, it is important to shed light on the potential channels that may incentivise countries to join an environmental agreement.

In this paper, we conjecture that, by affecting the terms of trade, environmental policy can give rise to trade creation and diversion effects that will shape the welfare implications of, and the incentives to join, international environmental agreements for the participating and non-participating countries. To explore this conjecture, we develop a N-country Q-goods perfectly competitive general equilibrium international trade model

[1] The United Nations Environmental Programme (UNEP) (www.unep.org) defines Multilateral Environmental Agreements (MEAs) as international agreements between three or more countries (agreements between two countries are referred to as "bilateral agreements") on how to jointly address environmental problems of a cross-border nature. Mitchell (2003) surveys multilateral and bilateral environmental agreements to number approximately 700 and over 1000, respectively. Similarly, according to the IEA database (http://iea.uoregon.edu/) there are 1280 MEAs and over 2100 bilateral agreements. The likely relatively higher homogeneity and the lower enforcement and coordination costs characterising smaller regions may explain the greater ease in forming smaller regional as opposed to larger environmental agreements.

in which a subset of countries form an environmental agreement.[2] We assume pollution to be trans-boundary and arising from production activities and that governments can affect environmental quality by means of an emissions tax. The assumption of free-trade, consistent with WTO objectives, facilitates a clearer identification of the various welfare effects emerging solely from environmental policy.

Our results confirm that an important channel for the welfare impact of environmental agreements are terms-of-trade induced trade creation and diversion effects. A major contribution of the paper is to show that terms of trade effects are crucial to the emergence of a negative relationship between the changes in welfare of signatories and non-signatories countries – whereby a Pareto welfare improving policy reform for the former may be welfare reducing for the latter. Thus, our results suggest that countries participating in an IEA may be able to use their environmental policies to manipulate the terms of trade so as to mitigate the negative impact of stricter emission control on competitiveness that underpins the pollution haven effects of environmental policy commonly highlighted by the literature.

The literature addressing environmental policy coordination mainly deals with the characterisation of optimal (first and second best) environmental and/or trade policy (see, e.g., Copeland, 1994; Neary, 2006; Keen and Kotsogiannis, 2014; Tsakiris et al., 2014) and policy reforms (Turunen-Red and Woodland, 2004; Copeland, 1994). The welfare consequences of policy reforms have mainly been analysed within a purely unilateral (e.g. Markusen, 1975; Krutilla, 1991; Copeland, 1994; Hatzipanayotou et al., 2008; Michael and Hatzipanayotou, 2013; Tsakiris et al., 2014, 2017) or a fully-cooperative (e.g. Keen and Kotsogiannis, 2014; Kotsogiannis and Woodland, 2013; Vlassis, 2013) context. To the best of our knowledge, the case of partial cooperation among a subset of countries has not been studied within this framework.

[2]Here we are not concerned with the issue of coalition formation and stability (Finus, 2003).

Alongside the trade theoretic approach within which this paper is developed, a game theoretic approach has primarily focused on environmental agreements' behaviour – from their formation, to participation incentives, and to factors contributing to their effectiveness (for recent reviews of this literature see, among others, Finus and Capparros, 2015 and Marrouch and Chaudhuri, 2016).[3] More recently, Al Khourdajie and Finus (2018) focus on the role of trade instruments, in the form of BCA, in offsetting countries' incentives to free ride in an IEA. In line with our results, this strand of the literature implies that terms of trade effects can potentially incentivise countries to join an IEA. While the game theory approach can study IEA behavioural aspects in a partially cooperative framework, it does not capture general equilibrium effects and is limited in its ability to characterise optimal policies and reforms.

The rest of the paper is organised as follows. Section 2 sets out the model, whilst Section 3 derives, as a benchmark, the optimal unilateral and cooperative policies in the absence of an international environmental agreement. Section 4 derives and discusses the optimal (country-specific and fully harmonized) environmental policy for the signatories. Section 5 determines the relationship between the welfare changes of the participating and non-participating countires. Section 6 concludes the paper.

2 The Model

We adopt a standard perfectly competitive general equilibrium international trade model characterised by N large open economies each producing and trading Q goods

[3]Papers focusing on issues of enforcement and on the size of IEAs (Hoel, 1992; Barrett, 1994; Eichner and Pethig, 2013) tend towards a pessimistic outlook about the stability of large IEAs. When IEA games include environmental or trade policy options (e.g., Eichner and Pethig, 2015; Dong and Zhao, 2009; Finus and Rundshagen, 2000), the results regarding participation and cooperation are mixed. In addition, there is a significant portion of the game theory literature that highlights the role of trade sanctions in increasing the stability of cooperation among countries (e.g., Hoel and Schneider, 1997; Carraro et al., 2006; Barrett, 1995, 1997).

under conditions of free-trade.[4] Pollution emissions are a by-product of production and are assumed to affect the representative consumer's welfare directly, whilst having no effect on the production capabilities of firms.[5] Factors of production are assumed to be internationally immobile and inelastically supplied. In what follows, superscripts and subscripts refer to the country and partial derivatives, respectively.

The vector of world prices is denoted by p and country j's Q-dimensional vector of emissions is denoted by z^j. Pollution is assumed to be fully trans-boundary; thus, global pollution is the sum of all countries' emissions:[6]

$$k = \sum_{j=1}^{N} i' z^j \ , \tag{2.1}$$

where i represents the N-vector of 1s and the prime indicates transposition.

Country j's consumer preferences are described by the expenditure function:

$$e^j(u^j, p, k) = min_{x^j}\{p' x^j : \ U^j(x^j, k) \geq u^j\} \ , \tag{2.2}$$

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

[4] The basic framework of analysis relies on that developed by Turunen-Red and Woodland (2004) and Keen and Kotsogiannis (2014). Our focus differs in that we consider partial cooperation, among a subset of countries, instead of full cooperation and we do not impose any restriction on trade – in line with WTO objectives (GATT article I and II). This allows us to analyse and isolate the effects of international environmental agreements on the welfare of both participating and non-participating countries.

[5] See Copeland (1994) and Keen and Kotsogiannis (2014).

[6] The analysis can easily be generalised to the case of partially trans-boundary pollution.

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

Each country imposes sector specific emission taxes, denoted by the vector s^j. In each sector, firms maximise revenue by choosing a feasible combination of emission (z^j) and output (y^j) for a given technology t^j and vector of endowments (v^j), resulting in the revenue function:

$$g^j(p, s^j, v^j) = Max_{y,z}\{p'y^j - s^{j\prime}z^j : \; y^j, z^j \epsilon t^j(v^j)\} \; . \tag{2.3}$$

The revenue function is convex, homogeneous of degree one in prices and emission taxes and is assumed to be twice continuously differentiable.[7] Hotelling's Lemma implies that the price derivatives of the revenue function give the vector of the net supplies of tradable goods $y^j = g^j_p$. The envelope property also implies that $z^j = -g^j_s$, i.e. the vector of emissions equals the marginal abatement costs.[8] Thus, totally differentiating z^j, we obtain the effect of the environmental policy on emission:

$$dz^j = -(g^j_{ss}ds^j + g^j_{sp}dp^j) \; , \tag{2.4}$$

where the first term on the right-hand-side represents the direct effect of the policy and the second term reflects the indirect effect arising from the impact of changes in prices on production. Thus, the change in global pollution is given by:

$$dk = -\sum_{j=1}^{N} i'(g^j_{ss}ds^j + g^j_{sp}dp) = -\sum_{j=1}^{N}(i'g^j_{ss}ds^j) - \sum_{j=1}^{N}(i'g^j_{sp}dp) \; . \tag{2.5}$$

[7]For the properties of the revenue function see Dixit and Norman (1980), Woodland (1982) and Copeland (1994).

[8]This, in turn, implies that global pollution can be rewritten as $k = -\sum_{j=1}^{N} i'g^j_s$.

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

$$e^j(u^j, p, k) = g^j(p, s^j) + s^{j\prime} z^j \ . \tag{2.6}$$

The market clearing condition requires that the sum of excess demands across the world should be equal to zero:

$$\sum_{j=1}^{N} m^j = \sum_{j=1}^{N} \{e_p^j - g_p^j\} = 0 \ . \tag{2.7}$$

Equations (2.1), (2.6), and (2.7) characterize the economy's equilibrium.[9]

3 Optimal Environmental Policy in the Absence of an International Environmental Agreement

In this section, we analyse environmental policy when the emission taxes are set unilaterally or in a fully multilateral cooperative setting. Although the results are well established in the literature,[10] they will offer a useful benchmark for the analysis of international environmental agreements.

By differentiating the market clearing condition (2.7), using (2.5), we can identify the effect of the environmental policy on international prices.[11]

$$\Lambda dp = \sum_{j=1}^{N} \left\{ \left[g_{ps}^{j\prime} + \left(\sum_{j=1}^{N} e_{pk}^j \right) i' g_{ss}^j \right] ds^j \right\} \ , \tag{3.1}$$

[9] The first tradable good is assumed to be the numeraire.

[10] See, e.g., Markusen, 1975; Keen and Kotsogiannis, 2014; Tsakiris et al., 2014, 2017; Vlassis, 2013; Kotsogiannis and Woodland, 2013.

[11] Each country's income effects are attached only to the numeraire good $e_{pu}^j = 0$. Relaxation of this assumption is feasible, without altering the qualitative nature of the results.

where

$$\Lambda = \sum_{j=1}^{N} \left[e_{pp}^{j\prime} - g_{pp}^{j\prime} - \left(\sum_{j=1}^{N} e_{pk}^{j} \right) i' g_{sp}^{j} \right] , \tag{3.2}$$

is the pollution augmented world net substitution matrix which is assumed to be of full rank and invertible. Thus:

$$dp = \Lambda^{-1} \sum_{j=1}^{N} \left\{ \left[g_{ps}^{j\prime} + \left(\sum_{j=1}^{N} e_{pk}^{j} \right) i' g_{ss}^{j} \right] ds^{j} \right\} , \tag{3.3}$$

which reflects the fact that changes in environmental policy affect prices via changes in both production levels, $\left(g_{ps}^{j\prime} ds^{j}\right)$, and, given the latter's effect on pollution, consumption levels, $\left(\left(\sum_{j=1}^{N} e_{pk}^{j}\right) i' g_{ss}^{j} ds\right)$.

To evaluate the impact of the environmental policy on welfare, we totally differentiate the budget constraint in (2.6) to obtain

$$e_{u}^{j} du^{j} = \left[-m^{j\prime} - s^{j\prime} g_{sp}^{j} + e_{k}^{j} \left(\sum_{j=1}^{N} i' g_{sp}^{j} \right) \right] dp - s^{j\prime} g_{ss}^{j} ds^{j} + e_{k}^{j} \sum_{j=1}^{N} \left(i' g_{ss}^{j} ds^{j} \right) . \tag{3.4}$$

Equation (3.4), indicates that an environmental policy change affects a country's welfare via its effects on: global pollution, $\left(e_{k}^{j} \sum_{j=1}^{N} \left(i' g_{ss}^{j} ds^{j}\right)\right)$, government revenue $\left(s^{j\prime} g_{ss}^{j} ds^{j}\right)$, and prices – where the latter in turn affect the terms of trade $\left(\left(-m^{j}\right) dp\right)$, government revenue $\left(-s^{j\prime} g_{sp}^{j} dp\right)$ and global pollution $\left(e_{k}^{j} \left(\sum_{j=1}^{N} i' g_{sp}^{j}\right)\right)$.

In order to derive the optimal non-cooperative environmental policy, we substitute (3.3) into (3.4) to rewrite the changes in the welfare function as

$$
\begin{aligned}
& -m^j \sum_{j=1}^{N} \left(\mu^j ds^j\right) \\
e_u^j du^j = \quad & -s^{j\prime} g_{sp}^j \sum_{j=1}^{N} \left(\mu^j ds^j\right) - s^{j\prime} g_{ss}^j ds^j \\
& + e_k^j \sum_{j=1}^{N} \left\{ \left[i' g_{ss}^j + i' g_{sp}^j \sum_{j=1}^{N} \mu^j \right] ds^j \right\} ,
\end{aligned}
\tag{3.5}
$$

where

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

from which the optimal unilateral environmental policy is

$$
s^{j\prime} = \; e_k^j i' - \Omega^j \tag{3.6}
$$

where $\Omega^j = \left[m^j - e_k^j \left(\sum_{l=1, l \neq j}^{N} g_{sp}^l \right) \right] \mu^j \left(g_{ss}^j + g_{sp}^j \mu^j \right)^{-1}$. Consistent with Keen and Kotsogiannis (2014), Tsakiris et al., (2014) and Markusen (1975), the optimal unilateral emission taxes account for the difference between the consumer's marginal willingness to pay for pollution abatement, $e_k^j i'$, and the impact of policy induced price changes on the terms of trade m^j and global emissions $e_k^j \left(\sum_{j=1}^{N} i' g_{sp}^j \right)$. A key difference with the extant literature is that, due to the fact that there is only one available policy instrument to address two distortions, the terms of trade and emission leakage effects are weighted by the direct effect of the policy on emission levels g_{ss}^j and its indirect effect through prices g_{sp}^j.[12]

In order to determine the cooperative optimal policy, we use the market clearing

[12] Our result is also consistent with the non-cooperative Nash equilibrium carbon permit price obtained by Copeland (1994) which equals the marginal willingness to pay for pollution abatement to an indirect terms of trade effect. Again, the key difference is the term reflecting the impact of policy induced price changes on global emissions which arises in our model as a result of the absence of trade policy to target trade related distortions. See Markusen (1975) for a discussion of corrective taxation in the case of a single policy instrument to deal with several distortions simultaneously.

condition in (2.7) together with the sum of the individual countries' welfare to write the change in world welfare as:[13]

$$\sum_{j=1}^{N} e_u^j du^j = \sum_{j=1}^{N} \left\{ \left[\left(\sum_{j=1}^{N} e_k^j i' \right) - s^{j\prime} \right] \delta^j \right\} \ , \tag{3.7}$$

where $\delta^j = \left[g_{ss}^j + g_{sp}^j \sum_{j=1}^{N} \mu^j \right] ds^j$. For $\delta \neq 0$, the optimal cooperative environmental tax is then:

$$s^{coop} = \left(\sum_{j=1}^{N} e_k^j i \right) \ . \tag{3.8}$$

Equation (3.8) implies that the cooperative second best optimal environmental policy should be uniform across the countries and 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 and country that generate them, each country sets the same emission tax across all the sectors, fully internalising the externality. This result is consistent with the related literature (e.g. Keen and Kotsogiannis, 2014; Kotsogiannis and Woodland, 2013; Vlassis, 2013).

Against this background, we now proceed to examine environmental policy within international environmental agreements.

4 Optimal Environmental Policy within an International Environmental Agreement

Assuming that a subset of countries sign an environmental agreement, we now determine the optimal environmental policy for the participating and the non-participating countries, denoted by the superscripts h and f respectively.

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

While the welfare of the non-participating countries and their optimal environmental policy are as described by equations (3.5) and (3.6), the policy induced changes in the aggregate welfare of the participating countries are given by:

$$\sum_{h=1,h\neq f}^{N} e_u^h du^h = \begin{array}{l} \sum_{h=1,h\neq f}^{N} \left\{ (-m^h) \sum_{j=1}^{N} (\mu^j ds^j) \right\} \\ - \sum_{h=1,h\neq f}^{N} \left\{ s^{h\prime} \left(g_{ss}^h ds^h + g_{sp}^h \sum_{j=1}^{N} (\mu^j ds^j) \right) \right\} \\ + \sum_{h=1,h\neq f}^{N} \left\{ e_k^h i' \sum_{j=1}^{N} \left\{ \left(g_{ss}^j + g_{sp}^j \sum_{j=1}^{N} \mu^j \right) ds^j \right\} \right\} \end{array} , \tag{4.1}$$

where the terms on the right-hand-side reflect, respectively, the change in the participating members' terms of trade, the impact of policy on their own emissions (directly and through production changes), and the cumulative impact of the policy on world emission leakage weighted by the participating countries marginal willingness to pay for pollution abatement.

If the environmental agreement results in country-specific taxes, the optimal tax s^{h^*} for the typical participating country h will be :

$$s^{h^*} = \sum_{h=1,h\neq f}^{N} e_k^h i' - \Phi \tag{4.2}$$

where $\Phi = \left\{ \left(\sum_{h=1,h\neq f}^{N} m^h \right) + \left(\sum_{h=1,h\neq h^*,f}^{N} s^h g_{sp}^h \right) - \left(\sum_{h=1,h\neq f}^{N} e_k^h i' \right) \left(\sum_{j=1,j\neq h^*}^{N} g_{sp}^j \right) \right\} \mu^{h^*} \left(g_{ss}^{h^*} + g_{sp}^{h^*} \mu^{h^*} \right)^{-1}$.

Proposition 1. *In the presence of an international environmental agreement, the second best country-specific optimal environmental policy for the participating countries will reflect their consumers' marginal willingness to pay for pollution abatement, their terms of trade effects, as well as the pollution externalities arising from the change in production in both participating and non-participating countries.*

Intuitively, maximisation of the joint welfare of the participating countries implies that for each one the environmental tax should reflect the difference between the union's marginal damage from emissions and the country-specific effects of the tax on terms of trade and emission leakages. Specifically, the term $\left(\sum_{h=1,h\neq f}^{N} m^h\right)$ reflects the policy's effect on the participating countries' terms of trade. The term $\left(\sum_{h=1,h\neq h^*,f}^{N} s^h g_{sp}^h\right)$ captures the internalisation of the policy externalities between the participating countries. This term has an interesting policy implication, which suggests that, as a result of the policy externality, a strict environmental policy by one member is compatible with 'softer' environmental standards in other participating countries. Finally, the term $\left(\sum_{h=1,h\neq f}^{N} e_k^h i'\right)\left(\sum_{j=1,j\neq h^*}^{N} g_{sp}^j\right)$ reflects the internalisation of the price and, consequently, production externalities arising from all other countries. The discrepancy between the participating countries' country-specific taxes reflects the inter-country differences in the direct and indirect impact (through changes in prices and production) of the tax on a country's emissions, $\mu^{h^*}\left(g_{ss}^{h^*} + g_{sp}^{h^*}\mu^{h^*}\right)^{-1}$. This highlights even further the fact that participating countries can set different levels of environmental taxes to address common targets whilst accommodating for country specific characteristics – as is, for example, the case within the European Union where all countries participate in the EU Emissions Trading System whilst having country specific environmental policy/targets.

If policy coordination results in full perfect tax harmonization within the signatories, the optimal tax will be given by:

$$s^{h^*} = \sum_{h=1,h\neq f}^{N} e_k^h i' - \Psi \tag{4.3}$$

where $\Psi = \left[\left(\sum_{h=1,h\neq f}^{N} m^h\right) - \left(\sum_{h=1,h\neq f}^{N} e_k^h i'\right)\left(\sum_{f=1,f\neq h}^{N} g_{sp}^f\right)\right]\left(\mu^{h^*}\right)\left(\sum_{h=1,h\neq f}^{N}\left(g_{ss}^h + g_{sp}^h\mu^h\right)^{-1}\right)$. As is clear from (4.3), the uniform tax depends on the participating countries' marginal willingness to pay $\left(\sum_{h=1,h\neq f}^{N} e_k^h i'\right)$, their terms of trade effects $\left(\sum_{h=1,h\neq f}^{N} m^h\right)$, and the externality of the non-participating countries weighted by the participating countries marginal damage $\left(\sum_{h=1,h\neq f}^{N} e_k^h i'\right)\left(\sum_{f=1,f\neq h}^{N} g_{sp}^f\right)$.

The differences between the optimal unilateral policy in equation (3.6) and the multilateral policies in equations (3.8), (4.2) and (4.3) reflect the fact that, contrary to the former, multilateral policies do not simply take into account a country's own consumer marginal damage from emissions, but also internalise the damage to the consumers of all the countries participating in the agreement. However, whilst in the multilateral case full coordination results in the internalisation of all the externalities, the policy coordination between members of an environmental agreement only internalises the externalities among member countries. Comparison between (4.2) and (4.3) suggests that the difference in the optimal tax between the two coordination modes among participating countries rests on the fact that the optimal country-specific environmental tax does not only internalise the intra-agreement externalities but also takes into account country-specific characteristics.

Given that in the case of full multilateral cooperation analysed in Section 3, the cumulative impact of the externality has been fully internalised, there are no distributional effects across countries through the terms-of-trade channel. Instead, as is the case for unilateral environmental policies, partial multilateral cooperation affects the terms-of-trade, stimulating trade creation and trade diversion effects. These terms of trade effects may generate incentives or disincentives for some countries to join an environmental agreement, or adopt environmental policies, when trade policy instruments are not available to correct the terms-of-trade distortion. Similarly, in the case of partial cooperation, the optimal environmental policy takes into account the direct impact of the policy on the IEA participants' emissions as well as on the emissions resulting from changes in production in the rest of the world.

Although the effects of the different policy scenarios on welfare levels are not easy to quantify within this framework, given its higher degree of internalisation of the policy externalities, the multilateral setting ought to be dominating from a welfare point of view.[14] However, in reality, we observe the prevalence of REAs. This may reflect the higher complexity of global coordination arising, for instance, from the conflict of interest among many and very heterogeneous countries. Clearly, however, the size of the agreement plays an important role in determining the level of the optimal environmental tax as it affects the cumulative marginal damage and the terms of trade effects. It also magnifies the externalities arising from the non-participating countries' production distortions. Whether an increase in the number of participating countries results in an increase in the optimal emission tax level will depend on the balance of those effects.

5 Welfare Effects of an IEA on Participating and Non-Participating Countries

In this section, we examine the welfare effects of an IEA's changes in policy on participating and non-participating countries.

Rewriting the market clearing condition in equation (2.7) as:

$$-\sum_{h=1,h\neq f}^{N} m^h = \sum_{f=1,f\neq h}^{N} m^f \, , \tag{5.1}$$

[14]Tsakiris at al.(2017) analyse the issue of efficiency of the non-cooperative versus the cooperative equilibrium of environmental policy, in a two country model with capital mobility. They conclude that in the presence of cross-border pollution, the non-cooperative settings of the available instruments is always inefficient relative to the cooperative ones.

and combining it with equations (4.1) and (3.5), we obtain

$$\sum_{h=1,h\neq f}^{N} e_u^h du^h = \begin{array}{c} \sum_{f=1,f\neq h}^{N} \left\{ -e_u^f du^f \right\} \\ +\sum_{j=1}^{N} \left\{ \left(\sum_{j=1}^{N} e_k^j i' - s^{j\prime} \right) \left(g_{ss}^j ds^j + g_{sp}^j \sum_{j=1}^{N} \mu^j ds^j \right) \right\} \end{array} . \tag{5.2}$$

To isolate the effects of the participating countries' policy changes, we assume that the non-participating countries are passive; equation (5.2) then becomes

$$\sum_{h=1,h\neq f}^{N} e_u^h du^h = \begin{array}{c} \sum_{f=1,f\neq h}^{N} \left\{ -e_u^f du^f \right\} \\ + \sum_{h=1,h\neq f}^{N} \left\{ \left(\sum_{j=1}^{N} e_k^j i' - s^{h\prime} \right) \left(g_{ss}^h ds^h + g_{sp}^h \sum_{h=1,h\neq f}^{N} \mu^h ds^h \right) \right\} \\ + \sum_{f=1,f\neq h}^{N} \left\{ \left(\sum_{j=1}^{N} e_k^j i' - s^{f\prime} \right) \left(g_{sp}^f \sum_{h=1,h\neq f}^{N} \mu^h ds^h \right) \right\} \end{array} , \tag{5.3}$$

while the change in the welfare of a non-participating country is given by:

$$e_u^f du^f = \begin{array}{c} -m^f \sum_{h=1,h\neq f}^{N} \left(\mu^h ds^h \right) \\ \left(e_k^f i' - s^{f\prime} \right) g_{sp}^f \sum_{h=1,h\neq f}^{N} \left(\mu^h ds^h \right) \\ +e_k^f i' \sum_{h=1,h\neq f}^{N} \left[g_{ss}^h ds^h + \left(\sum_{j=1,j\neq f}^{N} g_{sp}^j \right) \mu^h ds^h \right] . \end{array} \tag{5.4}$$

Equation (5.3) states that a change in the participating countries' environmental policy will affect their aggregate welfare through terms of trade (via changes in international prices) and emission leakage effects. As can be seen from the first term on the right-hand-side of the equation, there is a negative relationship between the change in welfare of participating and non-participating countries. This negative relationship hinges on the opposite terms of trade effects that the environmental agreement's policy has on participating and non-participating countries.[15] Clearly, these effects could not be highlighted by the existing trade/environmental literature, which has only considered the case of full cooperation within global environmental agreements.

Proposition 2. *There exists a negative relationship, arising from the terms of trade effects of the IEA's policy, between the participating and the non-participating countries' change in welfare.*

Changes in the signatories' environmental policy will also generate emission leakage among non-signatories. Specifically, the second term on the right-hand-side of (5.3) captures the participating countries' environmental policy's direct and indirect impact on their production, weighted by the difference between their emission taxes and the cumulative world marginal damage (which corresponds to the optimal tax of the full multilateral cooperative case). The last term on the right-hand-side of equation (5.3) captures the inter-bloc emission leakage effects of the policy resulting from its effects on international prices and production in non-participating countries, weighted by the difference between of the non-participating countries environmental tax and its full multilateral optimal level.

Equation (5.4) states that the change in the participating countries' emission taxes will affect the welfare of the non-participating ones through their impact on terms of trade as well as their intra- and inter-bloc emission leakage effects. The policy's terms of trade effect on a non-participating country will be determined by the country's initial trade status. The weights attached to the leakage effects reflect the marginal damage to the country's consumers and its difference to the country's emission tax. The overall effect to the welfare of a non-participating country resulting from a change in the

[15] To see this, isolate the terms of trade effects in equation (5.4) and substitute them for all the non-participating countries in (5.1). Using the resulting function, substitute the particpating countries' terms of trade in (4.1) to get (5.3).

emission taxes of the participating countries in an IEA will be determined by the magnitude of the described effects. However,equation (5.3) implies that an environmental policy reform that is Pareto improving for the IEA participating countries can reduce the level of welfare in the non-participating countries due to the trade creation and trade diversion effects of the policy. This result suggests that the terms-of-trade effects of environmental policy are an important channel affecting the incentives of countries to join an environmental agreement.

In order to isolate the effects of the policy on the terms of trade and to characterize a welfare improving reform, we follow Keen and Kotsogiannis (2014) and consider a special case by imposing some restrictive assumptions on the model. Specifically we set: $e_{pk} = 0$, $e_{pp} = 0$ and assume that one unit of production generates α units of emission, i.e. $g_p = -\alpha g_s$. We also assume that, at the initial equilibrium, $s^j = 0$ and, as before, that the non-participating countries are not policy active. In this case, the policy has an effect only through the terms of trade channel as is clear from the following equation:

$$\sum_{h=1,h\neq f}^{N} e_u^h du^h = -\left(\sum_{f=1,f\neq h}^{N} m^f\right)' \left(\sum_{j=1}^{N} g_{pp}^j\right)^{-1} \left(\sum_{h=1,h\neq f}^{N} g_{ss}^h ds^h\right) . \tag{5.5}$$

Given the above assumptions, substitution of equations (3.5) and (5.1) into (5.5) yields:

$$\sum_{h=1,h\neq f}^{N} e_u^h du^h = -\sum_{f=1,f\neq h}^{N} e_u^f du^f .$$

Then, a Pareto improving reform for the IEA's members is one such as $ds^h = -\kappa \sum_{f=1,f\neq h}^{N} m^f$ with κ being a positive scalar, which implies

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

since g_{pp} and g_{ss} are positive definite. Such a policy decreases the total trade with the non-participating countries and, as a result, has a negative effect on the non-participating countries' aggregate welfare.

The implications of this section can be summarised by the following proposition:

Proposition 3. *A Pareto improving environmental policy reform for the countries participating in an IEA can have a negative effect on the welfare of the non-participating countries due to its impact on the terms of trade.*

Intuitively, proposition 3 suggests that countries participating in an IEA can manipulate their terms of trade using their environmental policy resulting in trade creation among themselves and trade diversion with the rest of the world. This result implies that the terms of trade channel can weaken the pollution haven effect (whereby participation in an IEA can lead to a loss of competitive advantage in the regulated sector). Instead, due to the trade creation and diversion effects of the policy, countries can be worse off if not participating in an IEA. This result is in line with that of Al Khourdajie and Finus (2018) who show, in a game theoretic setup, that the manipulation of the terms of trade can lead to the formation of larger stable environmental agreements. This line of argument can contribute to explain the discrepancy (e.g. as highlighted by Marrouch and Chaudhuri, 2016) between the optimal size of environmental agreements predicted by the standard game theoretic literature and the much larger size observed in reality as with the Kyoto Protocol (1997) and the Paris Agreement (2015) which signed by 37 and 196 countries, respectively.

6 Conclusion

This paper has developed a N-country Q-goods general equilibrium framework to analyse unilateral and cooperative optimal environmental policies within an environmental agreement. The analysis highlights the importance of the terms of trade, via trade creation and trade diversion effects, for the characterisation of the optimal environmental policy and its welfare effects on participating and non-participating countries. The potential gains from increased trade may offset the increased costs of higher environmental taxes within an agreement. Another point to consider, which we have not explored in this paper, is that the trade creation and trade diversion effects of the IEA will affect global pollution. It is therefore theoretically possible that even when resulting in a global increase in welfare, an IEA may lead to an overall increase in pollution, depending on the production structure and relative pollution intensity of participating and non-participating countries.

A key finding of this paper is the negative relationship between the welfare changes of the participating and that of the non-participating countries arising from the terms of trade effects of the environmental policy. An interesting implication of the analysis is that countries may be willing to participate in an IEA as the terms of trade channel can contribute to mitigate the typical loss of comparative advantage resulting from stricter environmental regulation.

Whilst our analysis contributes to explain the nature of the externalities resulting from the formation of an environmental agreement, it does not allow us to quantify the exact welfare effects of the policy. This would require adopting a less general framework of analysis which we leave for future research.

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