Welfare Implications of an Emission-Neutral Trade and Environmental Tax Reform

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This paper examines the welfare effects of a trade tax reduction and an environmental tax increase that fix the domestic emission. The proposed reform is shown to improve welfare of a small country. In the large-country case, it improves domestic welfare if the initial trade tax is higher than the optimal level while the trading country gains from it due to its terms of trade improvement. These results suggest that trade liberalization and environmental protection under environmental agreements are compatible with each other.

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1 Introduction

As the world trade flows grow, a variety of challenging issues have newly arisen. The trade-induced expansion of environmental degradation, e.g. global climate changes and depletion of the ozone layer led by greenhouse gas emissions, is one of such problems to be resolved. For instance, WTO (2009, pp. 2-24) provides a number of graphs that illustrate a positive correlation between trade growth and a progress of climate changes. In order

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to cope with the environmental problem at the global level, multilateral environmental agreements (MEAs) as well as the discussions under the World Trade Organization (WTO) have been made. The Montreal Protocol and Kyoto Protocol are two of the most well-known examples of the MEAs, the former of which 'focused on phasing-out the consumption and production of nearly 100 ODS (ozone-depleting substances) chemicals,' (WTO, 2009, p. xv) and the latter of which 'requires Annex I countries to collectively reduce their emissions of the six main greenhouse gases (i.e. carbon dioxide, methane, nitrous oxide, hydrofl uorocarbons, perfluorocarbons, and sulphur hexafluoride) to at least 5 per cent less than 1990 emission levels.' (WTO, 2009, p. 71) Furthermore, the Post-Kyoto Protocol is now being discussed in response to the first commitment period of the Kyoto Protocol was expired in 2012. Then, one natural question arises: can these MEAs help improve the wellbeing of each nation as well as the world?

This paper examines the welfare effects of the requirement declared above in a criterion of a *strict* Pareto improvement. In other words, we ask whether all the countries gain from a coordinated reform of trade liberalization and environmental policies that follows the MEAs without an international income transfer.[1)] Specifically, constructing a competitive general equilibrium model comprising two large countries and transboundary pollution, we examine a unilateral reform of a trade tax reduction and an environmental tax increase that leaves domestic emission unchanged. Covering both the small country and large country cases, we demonstrate that trade liberalization can be beneficial without hurting the environment whether or not the country has market power in the world market. Then, we relate our results to the ongoing discussions on 'trade and the environment' under the WTO and MEAs. In this sense, this paper would serve

1) In contrast, a policy is defined to be *potentially* Pareto-improving when it raises welfare of the all the countries with a proper compensatory transfer.

to offer an economic rationale for environmental agreements, which is the main aim of Copeland and Taylor (2005).[2)]

There has been a large literature that shares a motivation similar to ours. Assuming a polluted small open economy, Copeland (1994) and Turunen-Red and Woodland (2002) propose several reforms of trade and environmental policies that improve welfare. Extending the model and argument of these papers to a large-country context, Turunen-Red and Woodland (2004) propose Pareto-improving reform strategies with and without international income transfers.[3)] Furthermore, Keen and Kotsogiannis (2012) apply the same framework to find the conditions for a global Pareto efficiency, and Vlassis (2013) demonstrates that pollution tax harmonization is potentially Pareto-improving. Finally, this paper is also related to Hatzipanayotou et al. (2008, 2013), Michael and Hatzipanayotou (2013), and Tsakiris et al. (2013) that commonly apply a competitive general equilibrium model to investigate welfare implications of tax reforms in the presence of pollution.[4)] While this paper is also along this strand of literature, our motivation is different from it in the sense that we consider a *unilateral* policy reform, which seems more feasible than *multilateral* reforms because reforms involving many countries are often difficult to settle.

2) One of the striking results in Copeland and Taylor (2005, p. 229) is that 'the increase in emissions in the unconstrained region (non-participants) may be small or even non-existent' even though the participating countries reduce their emission according to the Protocol.

3) While Turunen-Red and Woodland (2004) assume pollutions negatively affect consumer utility as is usually supposed in the literature, Kotsogiannis and Woodland (2013) extend the results to the case in which pollutions affect the production possibility set. See also Copeland (2011) and Chen and Woodland (2012) for a comprehensive survey.

4) The models employed in these papers differ in that Hatzipanayotou et al. (2013) and Michael and Hatzipanayotou (2008) assume a (single) small open country, Hatzipanaoytou et al. (2008) assume two small countries, and Tsakiris et al. (2013) assume two large countries.

This paper is organized as follows. Section 2 presents a model. Section 3 considers the welfare effects of the above-proposed reform in the cases of a small open country and two large countries, respectively. Section 4 concludes.

2 Model

This section develops a two-country perfectly competitive model in which the world commodity price is endogenously determined and an emission in a country arrives in the trading country. The small open country case will arise as a special case of the two-country model.[5] Suppose two countries (Home and Foreign) each of which produces and consumes two goods (Goods 1 and 2). Home is assumed to export Good 1, and levy an export tax t and an emission tax s both of which take a specific (per-unit) form whereas Foreign observes a laissez-faire policy.[6]

Letting p denote the world price of Good 1 measured by Good 2, the behavior of Home's consumer is described by an expenditure function:

$$e(p-t,u,z) \equiv \min_{x_1,x_2} \{(p-t)x_1 + x_2 | U(x_1,x_2,z) \geq u\},$$

where u is utility, z is a pollution in Home, $x_i, i = 1,2$ is consumption of Goods 1 and 2, and $U(\cdot)$ is a utility function.[7] Similarly, the production side is described by a revenue function:

$$r(p-t-s) \equiv \max_{y_1,y_2} \{(p-t-s)y_1 + y_2 | (y_1,y_2) \in Y\},$$

5) Our model is a simplified version of the model of Turunen-Red and Woodland (2004), Keen and Kotsougiannis (2012), and Kotsougiannis and Woodland (2013).

6) The import tariff case corresponds to $t < 0$. It is fair to say that our assumption that Foreign is passive is plausible by regarding Home as an Annex I (constrained) country of the Kyoto Protocol and Foreign as a non-participant (unconstrained) country.

7) Note that the consumer price is given by $p-t$ since the Home government imposes an export tax on Good 1.

where $y_i, i = 1, 2$ is output of Goods 1 and 2, and Y is a production possibility set. One can define the expenditure and revenue functions of Foreign, and an asterisk is attached to all the Foreign variables and functions. Assuming that production of Good 1 proportionally emits a pollutant, and that $\theta \in [0, 1]$ fraction of a country's emission reaches the other country, the pollution of Home and Foreign is given by

$$\begin{aligned}\text{Home} \quad &: z = r_p(p - t - s) + \theta r_p^*(p) \\ \text{Foreign} &: z^* = \theta r_p(p - t - s) + r_p^*(p),\end{aligned}$$

where subscript p refers to a derivative with respect to the price. When $\theta = 0$ (res. $\theta = 1$), pollution is local (resp. global).

Summarizing these assumptions, the model consists of three equations:

$$\begin{aligned}&e\left(p - t, u, r_p(p - t - s) + \theta r_p^*(p)\right) = r(p - t - s) \\ &+t\left[r_p(p-t-s) - e_p\left(p-t, u, r_p(p-t-s)+\theta r_p^*(p)\right)\right] + s r_p(p-t-s) \qquad (1) \\ &e^*\left(p, u^*, \theta r_p(p - t - s) + r_p^*(p)\right) = r^*(p) \qquad (2) \\ &e_p\left(p, u, r_p(p - t - s) + \theta r_p^*(p)\right) + e_p^*\left(p, u^*, \theta r_p(p - t - s) + r_p^*(p)\right) \\ &= r_p(p - t - s) + r_p^*(p). \qquad (3)\end{aligned}$$

Eq. (**??**) is an income-expenditure equality of Home, where $t[r_p(\cdot) - e_p(\cdot)]$ is an export tax revenue, and $s r_p(\cdot)$ is an emission tax revenue. Eq. (2) is a counterpart of Foreign, and (3) is a world market-clearing condition of Good 1. This system determines three endogenous variables u, u^* and p given the two taxes t and s.

Totally differentiating this system yields

$$\begin{bmatrix} e_u + te_{pu} & 0 & e_p - r_p + e_z\left(r_{pp} + \theta r_{pp}^*\right) + t\left[e_{pp} - r_{pp} + e_{pz}\left(r_{pp} + \theta r_{pp}^*\right)\right] - s r_{pp} \\ 0 & e_u^* & e_p^* - r_p^* + e_z^*\left(\theta r_{pp} + r_{pp}^*\right) \\ e_{pu} & e_{pu}^* & e_{pp} + e_{pp}^* - r_{pp} - r_{pp}^* + e_{pz}\left(r_{pp} + \theta r_{pp}^*\right) + e_{pz}^*\left(\theta r_{pp} + r_{pp}^*\right) \end{bmatrix} \begin{bmatrix} du \\ du^* \\ dp \end{bmatrix}$$

$$= \begin{bmatrix} t(e_{pp} - r_{pp} + e_{pz} r_{pp}) - s r_{pp} + e_z r_{pp} \\ \theta e_z^* r_{pp} \\ e_{pp} - r_{pp} + e_{pz} r_{pp} + \theta e_{pz}^* r_{pp} \end{bmatrix} dt + \begin{bmatrix} t r_{pp}(e_{pz} - 1) - s r_{pp} + e_z r_{pp} \\ \theta e_z^* r_{pp} \\ r_{pp}(e_{pz} + \theta e_{pz}^* - 1) \end{bmatrix} ds, \quad (4)$$

where subscript z represents a partial derivative with respect to the pollution. Eq. (4) offers a basis for the comparative statics analysis made in the subsequent section.

3 Emission-neutral reform

This section examines the welfare effects of a reduction in t and an associated change in s so that the Home emission r_p is constant. This requirement has been increasingly important in recent debates over climate change policies, and embedded in the Kyoto Protocol that 'requires industrialized countries to meet agreed levels of emission reductions over an initial commitment period that runs from 2008 to 2012.' (WTO, 2009, p. 68) In view of the fact that the Protocol is signed by both developing and developed countries, we begin with the case of a small open economy, and then proceed to the large country case.

3.1 Small open economy

Suppose that Home is a small open country.[8] Then, the equilibrium is given by Eq. (**??**) alone in which u is the only endogenous variable. In addition, the requirement that r_p is constant is achieved by adjusting two taxes according to $ds = -dt$ since this reform fixes the producer price $p - t - s$.[9] Making use of (4), the proposed emission-neutral reform affects the Home welfare as follows.

$$du|_{d(p-t-s)=0} = \frac{te_{pp}}{e_u + te_{pu}} dt. \tag{5}$$

8) This subsection contains nothing new since the results to follow are substantially the same as Proposition 2 in Michael and Hatzipanayotou (2013). Therefore, if the referees think that this subsection is redundant, we will omit it without any hesitation.

9) This reform is called a 'producer-price-neutral' reform by Michael and Hatzipanayotou (2008) and Hatzipanayotou et al. (2012).

Following the existing literature, let assume a Hatta Normality Condition that $e_u + te_{pu} > 0$.[10] Then, we can establish:

Proposition 1. *In the small-country case, the welfare effect of the emission-neutral export reduction and the associated change in emission tax on Home is positive.*

Proof. From the Hatta Normality Condition $e_u + te_{pu} > 0$ and $e_{pp} < 0$, we have

$$sign\{du\} = -sign\{t \cdot dt\}.$$

When the trade tax takes the form of an export tax, t is positive and its reduction is given by $dt < 0$, from which $du > 0$ follows. ||

The intuition for Proposition 1 is simple. In the present case of a small open country, the production-generated externality is the only market distortion, and hence the first-best outcome involves free trade (zero trade tax) and a positive emission (production) tax that is equal to the marginal damage from pollution. Since the requirement that $ds = -dt$ allows the country to approach the first-best solution above, the welfare effect turns out to be positive. In this sense, Proposition 1 offers a useful policy prescription that is (weakly) win-win, namely, welfare improves without hurting the environment.

10) See Hatta (1977a, b). By linear homogeneity of the expenditure function, we have an identity $e(p-t, u, z) \equiv (p-t)e_p(p-t, u, z) + e_0(p-t, u, z)$, where $e_0(\cdot)$ is (compensated) demand of the numeraire. Differentiating both sides with respect to u leads to $e_u = (p-t)e_{pu} + e_{0u}$, which is equivalent to $e_u + te_{pu} = pe_{pu} + e_{0u}$. That is, the inequality $e_u + te_{pu} > 0$ requires the total expenditure evaluated at the world prices to rise as a result of an increase in u. This is why Falvey and Kreickemeier (2011, p. 284) state that 'this is clearly a weak condition, and hence the assumption $\cdots$ is made throughout the literature on piecemeal trade reform.'

3.2 Large open economies

This subsection turns to the large-country case in which the world price p is endogenous. Then, the strategy $ds = -dt$ no longer makes constant either of the producer price $p - t - s$ and the Home emission level r_p. Thus, we must first define the coordinated reduction in t and a change in s so that the producer price is kept constant. Taking into account that p is endogenous, the emission-neutral (producer-price-neutral) reform is formalized by

$$d(p - t - s) = \left(\frac{\partial p}{\partial t} - 1\right) dt + \left(\frac{\partial p}{\partial s} - 1\right) ds = 0.$$

Utilizing the differentiated system of (4), the two taxes have to change according to

$$\begin{aligned} ds &= -\frac{\partial p/\partial t - 1}{\partial p/\partial s - 1} dt = -\frac{A}{B} dt \qquad (6) \\ A &\equiv te_{pu}\left[e^*_u\left(e^*_{pp} - r^*_{pp}\right) - e^*_{pu}\left(e^*_p - r^*_p\right)\right] + e_u e^*_u\left(e^*_{pp} - r^*_{pp}\right) \\ &\quad -e_{pu}e^*_u(e_p - r_p) - e_u e^*_{pu}\left(e^*_p - r^*_p\right) \\ B &\equiv te_{pu}\left[e^*_u\left(e^*_{pp} - r^*_{pp}\right) - e^*_{pu}\left(e^*_p - r^*_p\right)\right] + e_u e^*_u\left(e_{pp} + e^*_{pp} - r^*_{pp}\right) \\ &\quad -e_{pu}e^*_u(e_p - r_p) - e_u e^*_{pu}\left(e^*_p - r^*_p\right), \end{aligned}$$

where use is made of $e_u e_{pz} - e_z e_{pu} = 0$, which follows by differentiating the well-known identity $e_p(p, u, z) \equiv x(p, e(p, u, z))$ with respect to u and z: $e_{pu} = x_e e_u$ and $e_{pz} = x_e e_z$. Here, $x(\cdot)$ denotes an ordinary demand function of Good 1.

While the sign of A and B can be both positive and negative, we make an assumption that will play a key role in the subsequent arguments:

Assumption 1: $B < 0$.

One may claim that this assumption is extremely strong, but it can be justified as follows. When we manipulate $dr_p(p - t - s)/ds$, we have

$$\frac{dr_p(p-t-s)}{ds} = -\frac{r_{pp}B}{\text{determinant of the coefficient matrix of (4)}}.$$

That is, B measures the effect of the production tax on domestic production. Hence, the assumption of $B < 0$, coupled with the Walrasian stability, ensures a normal comparative statics outcome $dr_p/ds < 0$ so that a rise in the production tax decreases domestic production.[11] Once this is noticed, Assumption 1 seems less stringent than is thought.

Substituting (6) into ds in the right-hand side (RHS) of (4), it becomes

$$\text{RHS of (4)} = \frac{e_{pp}}{B}\begin{bmatrix} C \\ D \\ E \end{bmatrix} dt \tag{7}$$

$$C \equiv t^2 e_{pu}\left[e_u^*\left(e_{pp}^*-r_{pp}^*\right)-e_{pu}^*\left(e_p^*-r_p^*\right)\right]+t\left[e_u e_u^*\left(e_{pp}+e_{pp}^*-r_{pp}-r_{pp}^*+e_{pz}r_{pp}\right)\right.$$
$$\left.-e_{pu}e_u^*(e_p-r_p)-e_u e_{pu}^*\left(e_p^*-r_p^*\right)\right]+e_u e_u^* r_{pp}(e_z-s)$$

$$D \equiv \theta e_u e_u^* e_z^* r_{pp}$$

$$E \equiv te_{pu}\left[e_u^*\left(e_{pp}^*-r_{pp}^*\right)-e_{pu}^*\left(e_p^*-r_p^*\right)\right]+e_u e_u^*\left(e_{pp}+e_{pp}^*-r_{pp}-r_{pp}^*+e_{pz}r_{pp}+\theta e_{pz}^* r_{pp}\right)$$
$$-e_{pu}e_u^*(e_p-r_p)-e_u e_{pu}^*\left(e_p^*-r_p^*\right).$$

To identify the effect of the proposed reform on u, u^* and p, let us make a comparative statics by replacing the right-hand side of (4) with (7). Lengthy manipulations lead to

$$du|_{d(p-t-s)=0} = \frac{e_{pp}\left[e_u^*\left(e_{pp}^*-r_{pp}^*\right)-e_{pu}^*\left(e_p^*-r_p^*\right)\right]\left[t-\frac{e_u^*\left(e_p-r_p+\theta e_z r_{pp}^*\right)}{e_u^*\left(e_{pp}^*-r_{pp}^*\right)-e_{pu}^*\left(e_p^*-r_p^*\right)}\right]}{B}dt \tag{8}$$

$$du^*|_{d(p-t-s)=0} = -\frac{e_u e_{pp}\left(e_p^*-r_p^*+e_z^* r_{pp}^*\right)}{B}dt \tag{9}$$

$$dp|_{d(p-t-s)=0} = \frac{e_u e_u^* e_{pp}}{B}dt. \tag{10}$$

Given the negativity of B, (9) and (10) allow us to find that the coordinated tax reform improves Foreign's terms of trade (a fall in p), and hence raises

11) The Walrasian stability requires that the determinant of the coefficient matrix be negative.

Foreign's welfare. What is important is that the welfare effect on Home solely depends on the export tax regardless of the value of the emission tax. In order to prove the main result, we add another assumption the justification of which will be given later.

Assumption 2. $e_u^*\left(e_{pp}^* - r_{pp}^*\right) - e_{pu}^*\left(e_p^* - r_p^*\right) < 0.$

Then, we can establish:

Proposition 2. *In the large-country case with Assumptions 1 and 2, the welfare effect on Home is positive if the export tax is higher than the optimal level whereas the welfare effect on Foreign is positive.*

Proof. It suffices to prove the former part of the proposition since the latter part has already been demonstrated. Making use of (4), and solving the system of equations $\partial u/\partial t = \partial u/\partial s = 0$ for t, the optimal export tax t_{opt} is obtained as

$$t_{opt} = \frac{e_u^*\left(e_p - r_p + \theta e_z r_{pp}^*\right)}{e_u^*\left(e_{pp}^* - r_{pp}^*\right) - e_{pu}^*\left(e_p^* - r_p^*\right)}. \tag{11}$$

Since the Home government undoubtedly has an incentive to levy a positive export tax to improve its terms of trade, we should have Assumption 2 to ensure $t_{opt} > 0$. Relating (11) to (8), the welfare effect on Home is algebraically given by

$$sign\{du\} = -sign\left\{(t - t_{opt})\, dt\right\}.$$

Hence, Home gains from the suggested reform if the Home export is initially over-taxed as compared to the optimal level since $t - t_{opt} > 0$ and $dt < 0$. ||

While the large-country case complicates the model and analysis, the

argument that is parallel with Proposition 1 can be made. The effect on the Foreign welfare is obvious since reduced export taxes of Home increases its export, and hence lowers the world price of Good 1. This serves as a terms of trade gain for Foreign, thereby improving its welfare. In addition, a fall in the world price results in a contraction of Foreign production of Good 1. Recalling that the Home emission remains unchanged, the pollution in Foreign decreases, which additionally has a positive effect on the Foreign welfare.

The effect on the Home welfare is interpreted as follows. When Home has market power in the world market, the Home government is motivated to impose a positive export tax so as to enjoy the terms of trade gain. Hence, Home is subject to the terms of trade externality as well as a negative externality from pollution. If the export tax and the emission tax are adjusted so that (6) is satisfied, the effect from the latter externality is neutralized. Consequently, whether Home gains from the proposed reform is determined by resorting to the theory of optimal trade taxes. That is, if the Home export is higher than the optimal level, reducing it is beneficial, and vice versa in the case of under-taxes.

Remark. Thus far, we have confined attention to the export tax case. However, it is worth addressing the import tariff case since import tariffs prevail much more widely than export taxes. Note first that if the trade tax is an import tariff, t is negative, and its reduction is given by $dt > 0$. Then, it immediately follows from $sign\{du\} = -sign\{t \cdot dt\}$ that the emission-neutral tariff-tax reform benefits Home.

In contrast, the large-country case is not so straightforward. As to the welfare effect on Home, we can continue to claim that it is positive if the import tariff exceeds the optimal level by using the equation in the proof of Proposition 2: $sign\{du\} = -sign\{(t - t_{opt})\, dt\}$. This is because

reductions in tariffs that are higher than the optimal level imply $t - t_{opt} < 0$ and $dt > 0$. But, the welfare effect on Foreign becomes ambiguous since the coefficient of the right-hand side in (9) can be both positive and negative. All we can say is that the proposed reform benefits Foreign when $e^*_p - r^*_p + e^*_z r^*_{pp} < 0$. This is because the suggested reform raises the world price and Foreign emission, which, in turn, yields a gain from the terms of trade improvement and a loss from the expended pollution. That is, our reform succeeds in a strict Pareto improvement if the environmental concern in Foreign is small enough to have the above sufficient condition.

4 Concluding remarks

This paper has combined a theory of piecemeal policy reforms with an economic assessment of environmental agreements such as the Montreal Protocol, Kyoto Protocol and Post-Kyoto Protocol. We have shown that a small open country gains from a coordinated reform of an export tax reduction and an emission tax increase that fixes the domestic emission. Then, we have proceeded to the two-large-country model, demonstrating that the same reform is strictly Pareto-improving if the initial trade tax is higher than the optimal level. These results may hopefully contribute to literature that makes an economic assessment of the environmental agreements.

Despite the above novelty, we admittedly recognize that a number of questions are open. First, we have chosen a canonical model of perfect competition. But, we have already known that qualitatively the same results survive a model of a monopoly and oligopoly.[12)] Second, we have focused on a unilateral reform such that Foreign observes laissez-faire. While this assumption seems to well-approximate the reality in which several major

12) The non-competitive case is considered in a companion paper.

countries, e.g., the United States, leave the Kyoto Protocol. However, it is of great importance to pursue a welfare consequence of a multilateral reform. These agenda are left as a future direction of research that is worth trying.

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