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By

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Abstract

We develop a general two-country model with oligopolistic interdependence in which the firms make their output and emission decisions simultaneously. In this framework, we examine the effect of unilateral and multilateral reforms of emission taxes and abatement subsidies on global emission levels. We find that an increase in abatement subsidies — either unilateral or multilateral — unambiguously reduces global emission levels. In the presence of sufficient asymmetry in pollution intensities between the two countries, a unilateral or *equiproportional* multilateral increase in emission taxes can increase global emission levels. However, a multilateral increase of emission taxes of the *concertina* type unambiguously reduces global emission levels.

Key Words: Emission tax, abatement subsidy, policy reforms, multilateral, unilateral, concertina, equiproportional.
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1 Introduction

The impact of environmental policies in oligopolistic industries has been the subject of a large literature in recent years. However, very few of these studies allow for firm heterogeneity, even though this is a prevalent feature of industries. In this paper we construct a model of international competition between asymmetric firms, and examine the impact of environmental policy reforms adopted either unilaterally or multilaterally by the countries where the firms operate from. We consider two types of environmental policy, *viz.*, emission taxes and abatement subsidies, and we also allow for different patterns of firm heterogeneity and rules for policy reform. A key result of our paper is that different rules for multilateral reform of emission taxes can have qualitatively different effects on global emission levels.

The literature on environmental tax/subsidy policies is vast. Most of the early studies have either assumed perfect competition or abstracted from strategic interaction between firms even when allowing for imperfect competition. An extensive survey of the literature up to the early 1990s is given in Cropper and Oates (1992). More recent studies have focused on the effects of environmental policies in oligopolistic industries, and have also examined international aspects of environmental policy, strategic interaction between governments, and the links between environmental policy, the location decision of firms, innovation and market structure (see, for example, Conrad, 1993; Kennedy, 1994; Barrett, 1994; Ulph, 1996a, 1996b; Katsoulacos and Xepapadeas, 1995; Markusen *et al.,* 1993, 1995; Lahiri and Kayalica, 2002; and various contributions in Carraro, Katsoulacos and Xepapadeas, 1996, and Carraro and Siniscalo, 1997).

The purpose of emission taxes and abatement subsidies is, of course, to reduce pollution. However, these policies may not always have the desired effect. Baumol and Oates (1988, ch. 14), Mestelman (1982) and Kohn (1985) have shown that an increase in abatement subsidies may increase the total amount of pollution because it will increase total output in a perfectly competitive industry; this indirect effect may dominate any direct negative effect of subsidies on emissions per unit of output. Conrad and Wang (1993) have extended this result to an oligopoly with free entry. However, an increase in emission taxes unambiguously reduces emissions in these models, since in this case the direct and indirect effects of the policy work in the same direction.

Levin (1985) was the first to point out that an increase in emission tax may raise the total level of emissions in a homogeneous-product asymmetric oligopoly. In his model, different firms have different pollution intensities, and there are circumstances where the tax may increase the output of environmentally inefficient firms to such an extent that total pollution increases.[1] Others have shown that an emission tax may cause total emissions to rise when different firms are subject to different policy instruments (Stimming, 1999) or when firms face demand uncertainty and make decisions on their financial structure prior to competiting in the product market (Damania, 2000).

It is now widely acknowledged that pollution is a global issue and tackling it requires a multilateral approach. Pollution generated in one country often has far reaching implications for other countries. With these in mind, the international community has been very active in recent years organising international conferences to come up with binding commitments by individual countries to reduce pollution emissions, the so-called Kyoto protocol being the outcome of the last such high-profile conference. These multilateral approaches to policy reform have been going hand in hand with numerous unilateral reforms that many countries are actively pursuing. For example, the Supreme Court of India has recently enforced many national environmental regulations which the politicians were unable to implement in fear of backlash from vested interest groups. These developments in the policy arena have been accompanied by academic research on the subject and there is now a small theoretical literature that analyses the implications of unilateral and multilateral reforms of environmental

[1] Studies that relax the symmetry assumption in oligopoly models often reveal interesting and unexpected welfare properties of these models. See, for example, Bergstrom and Varian, 1985; Lahiri and Ono 1988, 1997; Symeonidis, 2003.

policies (see, for example, Beghin *et al.*, 1997; Copeland, 1994, 1996; Hatzipanayotou *et al.*, 2003; Ludema and Wooton, 1997; and Turunen-Red and Woodland, 2002a, 2002b).

In spite of the multilateral agreements on environmental policies, many countries have been reluctant to pursue the ratification of the agreements in the domestic legislatures. One of the arguments that is commonly used to justify this is the presence of asymmetries between countries and in the agreements themselves. For example, one argument used by the Bush administration in the U.S. to justify the non-ratification of the Kyoto protocol is that large countries with relatively more pollution-intensive technologies, such as China and India, are not required by the Kyoto protocol to do very much in terms of their pollution policies, and thus compliance by the U.S. is likely to be counterproductive. In this paper, we examine whether multilateral agreements can be designed in a way that the presence of asymmetries between countries cannot make the agreements counterproductive.

We do so by combining the two strands of the literature discussed above, *viz.*, environmental policies under asymmetric oligopolistic interdependence, on one hand, and unilateral and multilateral environmental policy reforms, on the other. In a formal sense our basic framework of analysis can be seen as an extension of that in Levin (1985) discussed above. More specifically, we develop a model of an international asymmetric oligopoly with product differentiation where the firms make their output and emission decisions simultaneously.[2] In this framework, we examine the effect of unilateral and multilateral reforms of emission taxes and abatement subsidies on global emission levels. We find that an increase in abatement subsidies — unilateral or multilateral — unambiguously reduces global emission levels. This result is consistent with previous literature where the number of firms is taken as fixed. We also find that a unilateral or an *equiproportional* multilateral increase in emission taxes can increase global emission levels. This result is consistent with a result in Levin (1985) which can be interpreted as an effect of equiproportional multilateral reform, although the exact

[2] In Levin (1985) emission is proportional to output and thus emission and output decisions are not separate ones.

circumstances where an increase in emission tax may cause pollution to rise are somewhat different in our model because of differences in the nature of the models. However, we find that a multilateral increase of emission taxes of the *concertina* type unambiguously reduces global emission levels.[3] Thus, our results indicate that, when designing multilateral reforms of environmental policies, policy makers should be careful with the choice of the rule as this may have important implications for the outcome of the reform.

The paper is structured as follows. We introduce the basic model in the next section. Sections 3 and 4 examine, respectively, the impact of unilateral and multilateral environmental policies on emission levels. The final section concludes.

2 The model

There are two countries, a and b, with n_a and n_b firms, respectively. All firms within a country produce a homogeneous product, but there is product differentiation across countries. Inverse demand functions in the two countries are given, respectively, by

$$p_a = f^a(x_a^1 + \cdots + x_a^{n_a}, x_b^1 + \cdots + x_b^{n_b}), \tag{1}$$

$$p_b = f^b(x_a^1 + \cdots + x_a^{n_a}, x_b^1 + \cdots + x_b^{n_b}), \tag{2}$$

where x_j^i is the output of firm i in country j. The profit function of firm i in country j is given by

$$\pi_j^i = p_j x_j^i - c_j^i(x_j^i) - g_j^i(\theta_j^i(x_j^i) - e_j^i) - t_j e_j^i + s_j(\theta_j^i(x_j^i) - e_j^i), \; j = a, b; \; i = 1, \cdots, n_j. \tag{3}$$

where $c_j^i(x_j^i)$ is the production cost of firm i in country j, $\theta_j^i(x_j^i)$ the gross pollution by firm i in country j, e_j^i the level of emissions of firm i in country j, the function $g_j^i(\theta_j^i(x_j^i) - e_j^i)$ is the cost of abatement function for firm i in country j, t_j the per unit emission tax in country j, and s_j the per unit abatement subsidy in country j.

[3]While our model assumes that firms compete by setting quantities in a differentiated market, the main results carry through to the case of price-setting firms.

All firms simultaneously choose a level of output and a level of emissions. In particular, firm i in country a chooses a level of output to maximise its profit according to the first-order condition

$$\frac{\partial \pi_a^i}{\partial x_a^i} = f_1^a x_a^i + f^a - c_a^{i\prime} - g_a^{i\prime}\theta_a^{i\prime} + s_a\theta_a^{i\prime} = 0,\ \ i = 1, \cdots, n_a, \tag{4}$$

while firm i in country b chooses a level of output according to the first-order condition

$$\frac{\partial \pi_b^i}{\partial x_b^i} = f_2^b x_b^i + f^b - c_b^{i\prime} - g_b^{i\prime}\theta_b^{i\prime} + s_b\theta_b^{i\prime} = 0,\ \ i = 1, \cdots, n_b, \tag{5}$$

wheref_k^j is the partial derivative of f^j with respect to the kth argument, $j = a, b$ and $k = 1, 2$.

In addition, firm i in country j chooses a level of emissions according to the first-order condition

$$\frac{\partial \pi_j^i}{\partial e_j^i} = g_j^{i\prime} - t_j - s_j = 0,\ \ j = a, b;\ \ i = 1, \cdots, n_j. \tag{6}$$

To ensure tractability of our model, we will assume symmetry within each country. As will be seen below, the driving mechanism for our results is the presence of asymmetries between the two groups of firms with respect to the pollution intensity of their technology, *i.e.*, the function $\theta_j^i(x_j^i)$. Assuming that all firms within each country have similar technology is not an unrealistic assumption if one thinks of this technology as being determined partly in response to country-specific past policies. Suppressing the firm-specific subscripts, equations (4)-(6) can be rewritten as

$$f_1^a(n_a x_a, n_b x_b)x_a + f^a(n_a x_a, n_b x_b) - c_a' - g_a'\theta_a' + s_a\theta_a' = 0, \tag{7}$$

$$f_2^b(n_a x_a, n_b x_b)x_b + f^b(n_a x_a, n_b x_b) - c_b' - g_b'\theta_b' + s_b\theta_b' = 0, \tag{8}$$

$$g_j' - t_j - s_j = 0, \qquad (j = a, b). \tag{9}$$

Using (9), equations (7) and (8) can be rewritten as

$$f_1^a(n_a x_a, n_b x_b)x_a + f^a(n_a x_a, n_b x_b) - c_a' - \theta_a' t_a = 0, \tag{10}$$

$$f_2^b(n_a x_a, n_b x_b)x_b + f^b(n_a x_a, n_b x_b) - c_b' - \theta_b' t_b = 0. \tag{11}$$

These two equations implicitly determine the equilibrium values of x_a and x_b.

We make the following assumptions:

Assumption 1: (i) $c_j' > 0,\ g_j' > 0,\ \theta_j' > 0,\ \ j = a, b$, (ii) $c_j'' > 0,\ g_j'' > 0,\ \theta_j'' > 0,\ j = a, b$, (iii) $yf_{ik}^j(Y) + f_l^j(Y) < 0$ for all $y \leq Y$ and $j = a, b;\ i, k, l = 1, 2$.

The first part of the assumption states that the gross pollution function and the cost functions are increasing, the second part that they are convex, and the third part corresponds to the 'normal' case in Seade (1980, pp. 483-484) and also to the strategic substitutes case in Bulow, Geanakoplos, and Klemperer (1985) and Dixit (1986). This also guarantees the concavity of each firm's profit function.

3 The impact of unilateral policy reform

We begin by examining the effect of an increase in emission tax or abatement subsidy in one country on the total level of emissions. We are particularly interested in identifying circumstances where environmental policies that are normally expected to reduce pollution have the opposite effect, namely an increase in total emissions. Totally differentiating (9), we get

$$g_a''[\theta_a' dx_a - de_a] = dt_a + ds_a, \tag{12}$$

$$g_b''[\theta_b' dx_b - de_b] = dt_b + ds_b. \tag{13}$$

Also, totally differentiating (10) and (11), we obtain

$$\pi_{11}^a dx_a + \pi_{12}^a dx_b = \theta_a' dt_a, \tag{14}$$

$$\pi_{21}^b dx_a + \pi_{22}^b dx_b = \theta_b' dt_b, \tag{15}$$

where

$$\pi_{11}^{a\prime} = x_a f_{11}^a + f_1^a < 0,$$

$$\pi_{22}^{b\prime} = x_b f_{22}^b + f_2^b < 0,$$

$$\pi_{11}^a = n_a \pi_{11}^{a\prime} + f_1^a - t_a \theta_a'' - c_a'' < 0,$$

$$\pi_{22}^b = n_b \pi_{22}^{b\prime} + f_2^b - t_b \theta_b'' - c_b'' < 0,$$

$$\pi_{12}^a = n_b (x_a f_{12}^a + f_2^a) < 0,$$

$$\pi_{21}^b = n_a (x_b f_{21}^b + f_1^b) < 0,$$

because of Assumption 1.

Solving (14) and (15) simultaneously for dx_a and dx_b, we obtain

$$\Delta \; dx_a = \theta_a' \pi_{22}^b \; dt_a - \theta_b' \pi_{12}^a \; dt_b, \tag{16}$$

$$\Delta \; dx_b = \theta_b' \pi_{11}^a \; dt_b - \theta_a' \pi_{21}^b dt_a, \tag{17}$$

where $\Delta = \pi_{11}^a \pi_{22}^b - \pi_{12}^a \pi_{21}^b > 0$ for the stability of the Cournot equilibrium.

From (16) and (17) it is clear that the abatement subsidies s_a and s_b have no effect on output levels. However, these subsidies have direct emission reducing effects as can be seen from (12) and (13) — although the abatement subsidy in one country does not affect the emission level in the other country. Therefore, abatement subsidies unambiguously reduce emissions. This result is formally stated as:

Proposition 1 *An increase in abatement subsidy in one country unambiguously reduces emission levels in that country and does not affect emission levels in the other country.*

A direct implication of this result is that any type of unilateral or multilateral increase of abatement subsidies will also unambiguously reduce emissions.

Turning to emission taxes, define $E(= n_a e_a + n_b e_b)$ as the global emission level. Making use of (12), (13), (16) and (17), we write

$$\frac{dE}{dt_a} = n_a \frac{de_a}{dt_a} + n_b \frac{de_b}{dt_a} = -\frac{n_a}{g''_a} + n_a \theta'_a \frac{dx_a}{dt_a} + n_b \theta'_b \frac{dx_b}{dt_a}$$

$$= -\frac{n_a}{g''_a} + \frac{n_a (\theta'_a)^2 \pi^b_{22}}{\Delta} - \frac{n_b \theta'_a \theta'_b \pi^b_{21}}{\Delta} \quad (18)$$

$$\frac{dE}{dt_b} = n_b \frac{de_b}{dt_b} + n_a \frac{de_a}{dt_b} = -\frac{n_b}{g''_b} + n_b \theta'_b \frac{dx_b}{dt_b} + n_a \theta'_a \frac{dx_a}{dt_b}$$

$$= -\frac{n_b}{g''_b} + \frac{n_b (\theta'_b)^2 \pi^a_{11}}{\Delta} - \frac{n_a \theta'_b \theta'_a \pi^a_{12}}{\Delta} \quad (19)$$

We are now in a position to examine one of the issues we raised earlier, viz., whether it is possible for an increase in emission tax in one of the countries to raise global pollution. Substituting π^b_{22} and π^b_{21} defined after (15) into (18), we get

$$\Delta \frac{dE}{dt_a} = -\frac{\Delta n_a}{g''_a} + n_a (\theta'_a)^2 [n_b x_b f^b_{22} + f^b_2 (1 + n_b) - t_b \theta''_b - c''_b]$$

$$- n_a n_b \theta'_a \theta'_b [x_b f^b_{21} + f^b_1]. \quad (20)$$

The sign of the above expression is in general ambiguous. To see this, consider the case of no product differentiation so that $f^b_1 = f^b_2$ and $f^b_{22} = f^b_{21}$. In this case from (20) we obtain

$$\Delta \frac{dE}{dt_a} = -\frac{\Delta n_a}{g''_a} + n_a n_b \theta'_a (\theta'_a - \theta'_b)(x_b f^b_{22} + f^b_2) + n_a (\theta'_a)^2 [f^b_2 - (t_b \theta''_b + c''_b)].$$

If the two countries are similar with respect to their production technology (*i.e.*, $\theta'_a = \theta'_b$) or the country that raises emission tax (country a) has a more pollution-intensive technology of production (*i.e.*, $\theta'_a > \theta'_b$), the right hand side of the above equation is negative because of Assumption 1. That is, an increase in emission tax in one country reduces total emissions. However, when country b has a sufficiently more pollution-intensive technology, *i.e.*, when $\theta'_b >> \theta'_a$, then from (20) it is clear that dE/dt_a can be positive: an increase in emission tax in the country with the less pollution-intensive technology may increase total emissions.

Under the linearity of demand and cost functions, while allowing for product differentiation, it is possible to obtain a tighter sufficient condition for an emission tax in a country to raise total emissions. If the inverse demand functions are given by

$$p_a = 1 - n_a x_a - \gamma n_b x_b,$$

$$p_b = 1 - n_b x_b - \gamma n_a x_a,$$

where $0 < \gamma < 1$ is an inverse measure of the degree of product differentiation, we have $f_1^a = f_2^b = -1$, $f_1^b = f_2^a = -\gamma$, and $f_{11}^a = f_{12}^a = f_{21}^b = f_{22}^b = 0$. Furthermore, $c_a'' = c_b'' = \theta_a'' = \theta_b'' = 0$. Then from (20) we get

$$\Delta \frac{dE}{dt_a} = -\frac{\Delta n_a}{g_a''} + n_a \theta_a' [n_b \gamma \theta_b' - \theta_a'(1 + n_b)], \tag{21}$$

whence it follows that $dE/dt_a > 0$ if (i) g_a'' is very large and (ii) $\theta_b' > \theta_a'(1 + n_b)/(\gamma n_b)$. Note that the likelihood that an increase in emission tax in the country with the less pollution-intensive technology will cause an increase in global emissions is higher the steeper the abatement cost function in the country with the more pollution-intensive technology, the larger the degree of heterogeneity between the two countries' technologies, the lower the number of firms in each country, and the lower the degree of product differentiation.

The intuition for this result is as follows. An increase in emission tax in country a causes each firm in that country to reduce its emissions. It has no direct effect on the firms in the other country. However, the increase in the emission tax in country a raises the unit cost of production for all the firms in that country giving the firms in the other country a competitive advantage. This reduces output levels of the firms in country a and raises that in country b. The increase in output levels in country b leads to an increase in emissions in that country. This latter effect can dominate when country b has a sufficiently more pollution-intensive technology, because in that case even a small output increase in country b will lead to a large increase in emissions in that country and may therefore cause the total level of emissions to rise despite a decrease in emissions in country a. This result is stated formally as:

Proposition 2 *A unilateral increase in emission tax in one country can increase global emission levels if the other country has a significantly more pollution-intensive technology than the first country.*

4 The impact of multilateral policy reform

Having established the possibility that an unilateral increase in the level of emission tax in one country can increase total emissions by the two countries, we now want to examine whether a concerted multilateral increase in emission taxes may unambiguously reduce total pollution. As is well known, there are a number of different rules which a multilateral reform can follow. The two most common rules are (i) an *equiproportional* rule, and (ii) a *concertina* rule (see, for example, Turunen-Red and Woodland (2002a)). In the former case, percentage changes in the tax rates are the same, *i.e.*,

$$dt_i = \alpha t_i, \qquad i = a, b, \tag{22}$$

where α is a positive number. In the latter case, the absolute level of changes in the two tax rates are the same, *i.e.*,

$$dt_i = \delta, \qquad i = a, b, \tag{23}$$

where δ is a positive number.

If the initial tax rate in a country is very small, then the equiproportional rule effectively means that there is very little increase in the tax rate in that country. The impact of the reform is then mainly driven by the impact of the tax increase in the country with the relatively high tax rate. In this case it can be shown, by appealing to our earlier result, that the equiproportional rule cannot always guarantee a decrease in total emissions. In particular, total emisions will increase if a country has a very low initial tax rate *and* a sufficiently more pollution-intensive technology than the other country. This combination is not unrealistic: part of the reason for the presence of a pollution-intensive technology in a country could be a low level of environmental taxation in that country.

We now examine the effect of a multilateral increase in emission taxes according to the concertina rule on total emissions, starting with the benchmark case of no product differentiation. Note that with the concertina rule, countries with low initial levels of emission taxes cannot get away with small increases in the taxes. When there is no product differentiation, *i.e.*, $f_1^a = f_2^b = f_2^a = f_1^b$ and $f_{11}^a = f_{22}^b = f_{21}^b = f_{12}^a$, and the concertina rule is applied, adding (18) and (19) we find

$$\begin{aligned} \frac{\Delta}{\delta} dE &= \Delta \frac{\partial E}{\partial t_a} + \Delta \frac{\partial E}{\partial t_b} \\ &= -\frac{\Delta n_a}{g_a''} - \frac{\Delta n_b}{g_b''} - \left[n_a \left(\theta_a'\right)^2 \left(t_b \theta_b'' + c_b''\right) + n_b \left(\theta_b'\right)^2 \left(t_a \theta_a'' + c_a''\right) \right] \\ &+ n_a n_b \left[\alpha_1 f_1^a + \alpha_2 f_{11}^a \right], \end{aligned} \tag{24}$$

where

$$\begin{aligned} \alpha_1 &= \left(\theta_a' - \theta_b'\right)^2 + \frac{\left(\theta_b'\right)^2}{n_a} + \frac{\left(\theta_a'\right)^2}{n_b}, \\ \alpha_2 &= \left(\theta_a'\right)^2 x_b + \left(\theta_b'\right)^2 x_a - \theta_a' \theta_b' (x_a + x_b). \end{aligned} \tag{25}$$

It can be easily verified that $\alpha_2/\alpha_1 < n_a x_a + n_b x_b$ and therefore using Assumption 1 it follows that $\alpha_1 f_1^a + \alpha_2 f_{11}^a < 0$. Hence $dE < 0$: a multilateral reform of emission taxes according to the concertina rule unambiguously reduces global pollution.

This result is robust to the introduction of product differentiation, at least for linear demand and cost functions. If the inverse demand functions are given by

$$p_a = 1 - n_a x_a - \gamma n_b x_b,$$

$$p_b = 1 - n_b x_b - \gamma n_a x_a,$$

where $0 < \gamma < 1$ is an inverse measure of the degree of product differentiation, we have $f_1^a = f_2^b = -1$, $f_1^b = f_2^a = -\gamma$, $f_{11}^a = f_{12}^a = f_{21}^b = f_{22}^b = 0$, and $c_a'' = c_b'' = \theta_a'' = \theta_b'' = 0$. Then from (20) and the corresponding expression for country b, we obtain

$$
\begin{aligned}
\frac{\Delta}{\delta} dE &= \Delta \frac{\partial E}{\partial t_a} + \Delta \frac{\partial E}{\partial t_b} \\
&= -\frac{\Delta n_a}{g_a''} + n_a \theta_a' [n_b \gamma \theta_b' - \theta_a'(1+n_b)] - \frac{\Delta n_b}{g_b''} + n_b \theta_b' [n_a \gamma \theta_a' - \theta_b'(1+n_a)] \\
&= -\frac{\Delta n_a}{g_a''} - \frac{\Delta n_b}{g_b''} - n_a (\theta_a')^2 - n_b (\theta_b')^2 - n_a n_b \left[(\theta_a' - \theta_b')^2 + 2(1-\gamma)\theta_a' \theta_b' \right], \qquad (26)
\end{aligned}
$$

whence it follows that $dE < 0$.

The results of this section are stated formally as:

Proposition 3 *Whereas a multilateral equiproportional increase in emission taxes can sometimes increase global emission levels, an increase in emission taxes according to the concertina rule unambiguously reduces global emission levels.*

The above result has important implications for the design of multilateral environmental policy reforms. In particular, if the policy makers follow the concertina rule in designing a multilateral reform of emission taxes, the presence of asymmetries between nations cannot cause the reform to increase total emissions and thus cannot be used as an excuse by any country for not implementing the multilateral agreement.

5 Conclusion

The world today is not only very diverse in terms of incomes, endowments and technologies, but it is also highly interlinked. Unilateral actions by one country can have serious adverse effect on other countries. There is no better example of these international externalities than environmental degradation. However, although serious headways have been made on multilateral agreements on international trade, such agreements on environment have faced serious obstacles from important sources. Asymmetries in pollution technologies between nations and in the agreements themselves are often used to justify the non-ratification of environmental treaties. In this paper we have examined if the multilateral reforms of environmental policies could be designed in a way that asymmetries in pollution technologies cannot make the reforms counterproductive.

We develop a two country model of oligopolistic interdependence in which asymmetric firms decide on their output and emission levels simultaneously. In this framework we examine the effect of unilateral and multilateral reforms of abatement subsidies and emission taxes on the level of global emission. We find that any increase in abatement subsidies unambiguously reduces global welfare. This result is consistent with previous literature where the number of firms is taken as fixed. We also find that unilateral and equiproportional multilateral increase in emission taxes may increase global emission if the firms are sufficiently asymmetric in terms of their pollution technologies. In particular, if a country with an initial low level of emission tax has a significantly more pollution-intensive technology than the other country, an equiproportional multilateral increase in emission taxes will increase global emission levels. However, if the multilateral reform is of the concertina type — i.e., both countries increase their emission taxes by the same absolute amount — then the reform will unambiguously reduce global emission levels. Thus our study suggests that there does indeed exist a rule for multilateral reform of emission taxes under which asymmetries between countries cannot make the reform counterproductive.

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