International Capital Mobility and Pollution Tax Coordination

Chi-Chur Chao
Chinese University of Hong Kong

and

Eden S.H. Yu
City University of Hong Kong

1. INTRODUCTION

As the world economy becomes more and more interdependent, the importance of coordination in the design and implementation of various economic policies among nations has gained increasing recognition. The current trend toward trade liberalization has led some countries in regional trading blocks to advocate policy reforms with harmonization in mind. For example, proposals have been put forward to adopt indirect taxes in a harmonization fashion to replace tariffs. The motivation and welfare implications of such policy reforms have been studied, e.g., Hatzipanayotou et al. (1994) on tariffs and consumption taxes, and Lahiri and Raimondos-Møller (1998) on indirect taxes.

As economies become increasingly integrated at the global level, many critical issues of a transboundary nature are bound to arise. An issue which has attracted a great deal of attention recently involves the environment.[1] Complex relationships exist among international trade, investment and the environment. For many developing nations, the shortage of capital is a major obstacle in implementing their developmental programs. To mitigate this obstacle, developing countries often provide favorable credits for foreign investment and/or permit lax regulatory requirements on pollution. Generally such policies attract foreign investment and result in the international movement of capital, particularly from polluting industries in economies with heightened environmental consciousness to countries with less environmental awareness. One vivid example, among many, was a proposal in 1990s by Taiwan's Formosa Plastic Conglomerate to set-up petrochemical plants in a coastal province of China after the plan experienced strong opposition at home.

Recognizing the detrimental effects of global warming and acid rain, pollution is an emerging issue with global ramifications and concerns. In this paper, we examine the welfare implications of a variety of environmental policies in the context of a two-country setting. Specifically, we concentrate on the effects of several alternative pollution taxes on capital allocation and welfare effects. Conceptually, the two countries may consider freely setting the tax rates on pollution, which maximize some collective objective function. Nevertheless, due to mutual mistrust and gaps in the social valuation of pollution, the involved countries prefer to explore some measures of coordination of a manageable scope as a first step towards future full-fledged coordination and cooperation. In this regard, three types of coordination schemes of pollution tax are considered: (i) compression of the tax structure by decreasing the highest tax rate, i.e., the “concertina” rule;[2] (ii) uniform radial adjustments of tax rates toward optimal rates; and (iii) harmonization of tax rates. Our key finding is that pollution tax coordination via uniform radial adjustments of tax rates is likely to be welfare-superior to the other types of tax changes. However, if there is a large disparity between the initial tax rates, the harmonization of pollution taxes may lead to a larger welfare improvement for the participating nations.

This paper is organized as follows. Section 2 provides a two-country model in which the two nations are linked by capital mobility. In section 3, the effects of pollution taxes on capital movement and pollution levels in both countries are deduced. Furthermore, the welfare effects of the alternative schemes of pollution taxes are examined, and the individual (second-best) and jointly (optimal) pollution tax rates for each country are derived. We then compare and rank the welfare effects for the alternative schemes of tax coordination. Several concluding remarks are provided in section 4.

2. THE MODEL

Consider a region consisting of two countries, home and foreign. Each country has two sectors, producing two goods, X and Y, with prices p_X and p_Y, respectively. In this paper, pollution is discharged by both industries, so that the production of good i yields a same type of pollution, denoted by Z_i, $i = X, Y$. Total pollution emission in each nation is: $Z = Z_X + Z_Y$. Pollution is a public "bad" and is regulated by authorities by imposing pollution taxes in both countries. Firms pay fines instead of cleaning up production.[3] The variables with asterisks denote those for the foreign country.

The production of goods requires capital and other factors. Capital is mobile between the two countries but other factors are not. The home country receives foreign capital; let its endowment of capital be $\overline{K}$ and inflows of foreign capital be K. By choosing good Y as numeraire (i.e., $p_Y = 1$), the relative price of good X is $p = p_X/p_Y$. Let the tax rate on pollution Z be s, which is the focus of the present chapter. The value of home's gross domestic product (GDP) is decreased by the amount of the pollution tax. The home's GDP can be defined as: $R(p, 1, s, \overline{K} + K) = \max \{pX + Y - sZ: (X, Y, Z) \in \Gamma(\overline{K} + K)\}$, where $\Gamma(\cdot)$ represents the domestic technology set.[4] Let the subscripts represent the partial derivatives; by Shephard lemma we have $R_p = X$, $R_s = - Z$ and $R_K = r$, where r is the domestic rate of return on capital. The foreign GDP function can be similarly defined as: $R^*(p, 1, s^*, \bar{K}^* - K)$, where $R_p^* = X^*$, $R_s^* = - Z^*$ and $R_K^* = r^*$.

Since capital is perfectly mobile between the two countries, its domestic rate of return (r) is, in equilibrium, equal to the foreign rate (r^*):

$$R_K(p, 1, s, \bar{K} + K)) = R_K^*(p, 1, s^*, \bar{K}^* - K). \qquad (1)$$

The home and foreign economies are connected by the flows of capital. To focus on analyzing the welfare effects of capital movements caused by international differential pollution taxes, we assume away the terms-of-trade effects by treating the goods prices, p, as exogenous.[5] Solving (1) yields the effects of pollution taxes on capital movement:

$$dK/ds = - R_{Ks}/(R_{KK} + R_{KK}^*) < 0, \qquad (2)$$

$$dK/ds^* = R_{Ks}^*/(R_{KK} + R_{KK}^*) > 0, \qquad (3)$$

where $R_{KK} = \partial R_K/\partial K < 0$, expressing the diminishing marginal product of capital. Notice that $R_{Ks} = R_{sK} = - \partial Z/\partial K < 0$ by assuming that the capital-intensive sector produces more pollutants.[6] Equations (2) and (3) imply that the inflows of capital to the home country will be decreased (increased) when the home (foreign) country raises its pollution taxes. This result suggests that differential environmental regulations can provide a reason for international capital movements apart from those known in the literature, e.g. bypassing trade barriers.[7]

Consider next the effects of pollution taxes on pollution emissions in each country. From the GDP functions, the levels of pollution emissions in the home and foreign countries are determined by

$$R_s(p, 1, s, \bar{K} + K) = - Z, \qquad (4)$$

$$R_s^*(p, 1, s^*, \overline{K}^* - K).) = - Z^*. \quad (5)$$

Free international mobility of capital in the present framework means that the pollution level in each country is affected not only by its own pollution tax but also indirectly by the other country's pollution tax. This can be verified by differentiating (4) and (5), and then using (2) and (3) to yield:

$$dZ/ds = - R_{ss} – R_{sk}(dK/ds) < 0, \quad (6)$$

$$dZ/ds^* = - R_{sk}(dK/ds^*) > 0, \quad (7)$$

$$dZ^*/ds = R_{sK}^*(dK/ds) > 0, \quad (8)$$

$$dZ^*/ds^* = - R_{ss}^* + R_{sK}^*(dK/ds^*) < 0, \quad (9)$$

where $R_{ss} = - \partial Z/\partial s > 0$ and $R_{sK} = - \partial Z/\partial K < 0$.[8] While pollution taxes dampen pollution emissions, capital inflows induce more pollution where the capital-intensive sector is more polluting than the other sector. Equations (6) – (9) indicate that a rise in a country's pollution tax rate lowers its pollution emissions but induces a higher level of pollution in the other country via an outward movement of capital into the latter. In the present framework, as s increases, Z falls and capital inflows decrease in the home country (leading to more capital and hence pollution in the foreign country).

We turn to the demand side of the economy. The minimum spending on goods for achieving a specified level of utility, u, defines the expenditure function: $E(p, 1, Z + \alpha^*Z^*, u) = \min \{pD_X + D_Y: U(D_X, D_Y, Z + \alpha^*Z^*) = u\}$ with respect to D_X and D_Y. Pollution, whether emitted by domestic or foreign producers, hurts domestic consumers. Here, transboundary pollution is introduced and captured by α^*, which is a fraction of the amount of foreign pollution spillover into the home country. The marginal damage caused by pollution is represented by $E_Z = \partial E/\partial(Z + \alpha^*Z^*)$, where $Z + \alpha^*Z^*$ is the total pollution level in the home country. A similar expenditure function applies to the foreign country as $E^*(p, 1, Z^* + \alpha Z, u^*)$, where $E_Z^* = \partial E^*/\partial(Z^* + \alpha Z) > 0$ and $Z^* + \alpha Z$ is total pollution in foreign country with $0 < \alpha < 1$.

Finally, the equilibrium conditions for the home and foreign countries can be represented by their respective budget constraints, as follows:

$$E(p, 1, Z + \alpha^* Z^*, u) = R(p, 1, s, \overline{K} + K)) + sZ - rK, \tag{10}$$

$$E^*(p, 1, Z^* + \alpha Z, u^*) = R^*(p, 1, s^*, \overline{K}^* - K) + s^* Z^* + rK. \tag{11}$$

Note that pollution tax revenue sZ or s^*Z^* is redistributed to consumers in a lump-sum fashion.[9] In addition, the return on foreign capital, rK, is fully repatriated from the home country back to the foreign country.

Equations (10) and (11) can be used to examine the welfare effects of small changes in the rates of pollution taxes.

3. WELFARE EFFECTS OF POLLUTION TAXES

Adjustment in pollution taxes can result in changes in welfare in both countries. Such welfare effect can be obtained by differentiating the budget constraints of both countries in (10) and (11):

$$du = -(E_Z - s)dZ - \alpha^* E_Z dZ^* - Kdr, \tag{12}$$

$$du^* = -(E_Z^* - s^*)dZ^* - \alpha E_Z^* dZ + Kdr, \tag{13}$$

where, by choice of units, $E_u = E_u^* = 1$. Pollution affects welfare in two ways. First, pollutants inflict consumers by the marginal damages, E_Z and E_Z^*. Second, tax revenue collected from polluters can be used to promote welfare. These two conflicting effects of pollution tax render the welfare impact ambiguous. More importantly, the transboundary movement of pollution has welfare ramifications for both countries. Apparently, some sort of international coordination of environmental policy (barring full-fledged cooperation for the time being) is highly desirable for improving each and global welfare. We now focus on analyzing the case of Pareto improving tax coordination, in which changes in pollution taxes will improve domestic welfare while keeping welfare of the other country intact.

Setting $du^* = 0$ in (13) and then substituting it into (12), we obtain:

$$du = -(E_Z - s)dZ - \alpha^* E_Z dZ^* - (E_Z^* - s^*)dZ^* - \alpha E_Z^* dZ. \qquad (14)$$

For a given foreign pollution tax s^*, the welfare effect of changes in the home pollution tax rate is:

$$du/ds = -(E_Z - s)dZ/ds - \alpha^* E_Z dZ^*/ds - (E_Z^* - s^*)dZ^*/ds - \alpha E_Z^* dZ/ds. \qquad (15)$$

In view of (6) and (8), du/ds may take any sign, implying the existence of a second-best optimal pollution tax rate (s^o), which can be derived as follows:

$$s^o = A - s^*(dZ^*/ds)/(dZ/ds), \qquad (16)$$

where $A = (E_Z + \alpha E_Z^*) + (E_Z^* + \alpha^* E_Z)(dZ^*/ds)/(dZ/ds)$. This (second-best) pollution tax can be illustrated in Figure 1 depicting the space of the two policy instruments of s and s^*.[10] Note that s^o is related to s^*. Recalling that $dZ/ds < 0$ and $dZ^*/ds > 0$, the s^o schedule is positively sloped. We consider the case that $A > 0$ and $-(dZ^*/ds)/(dZ/ds) < 1$; the s^o schedule is shown with a positive intercept and a slope less than the 45° ray in Figure 1. For any given s^*, vertical adjustments of s towards the s^o schedule improve the home welfare.

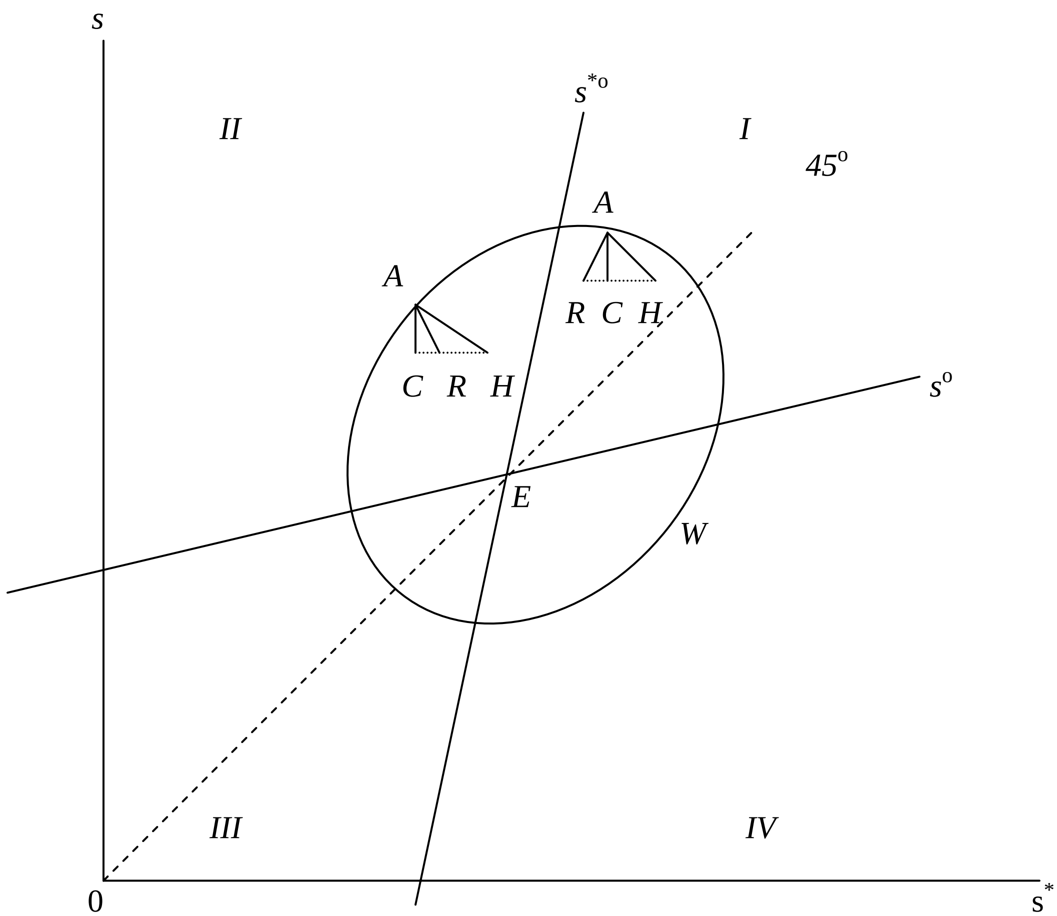

Figure 1: Welfare effects of domestic and foreign pollution taxes.

Similarly, from (14), the impact of changes in foreign pollution tax rate on the home welfare for a given home pollution tax rate s can be obtained as

$$du/ds^* = -(E_Z - s)dZ/ds^* - \alpha^* E_Z\, dZ^*/ds^* - (E_z^* - s^*)dZ^*/ds^* - \alpha E_z^*\, dZ/ds^*. \quad (17)$$

The second-best optimal foreign pollution tax rate (s^{*o}) is obtained by setting $du/ds^* = 0$ in (17) as

$$s^{*o} = B - s(dZ/ds^*)/(dZ^*/ds^*), \quad (18)$$

where $B = (E_Z^* + \alpha^* E_Z) + (E_Z^* + \alpha^* E_Z)(dZ/ds^*)/(dZ^*/ds^*)$. Note that s^{*o} is positively related to s and B can take any sign. We plot in Figure 1 the locus of the (second-best) optimal foreign pollution tax rates as the schedule s^{*o} under the slope condition that $-(dZ/ds^*)/(dZ^*/ds^*) < 1$, i.e., the schedule lies above the 45^o ray. Apparently, for any given s, horizontal movements of s^* towards s^{*o} schedule improve the home welfare.

International tax coordination involves adjustments in s and/or s^*. Using (16) and (18), we can rewrite the welfare expression in (14) in an illuminating way:

$$du = (dZ/ds)(s - s^o)ds + (dZ^*/ds^*)(s^* - s^{*o})ds^*. \quad (19)$$

Changes in welfare depend upon changes in the pollutions tax rates. For $du = 0$, we obtain for the home country a representative iso-welfare contour à la Neary (1995), depicted by a potato-shaped ellipsoid W in Figure 1. Clearly, any small movements of s and s^* towards the intersection of the two schedules at point E improve home welfare. The (first-best) optimal solution for s and s^*, denoted by s^{oo} and s^{*oo} at point E, can be obtained by solving (16) and (18) as

$$s^{oo} = E_Z + \alpha E_Z^*, \quad (20)$$

$$s^{*oo} = E_Z^* + \alpha^* E_Z. \quad (21)$$

That is, the jointly optimal pollution tax rates are the rates set by each country according to the Pigouvian rate (i.e., the marginal damage of pollution). Note that tax revenue based on the Pigouvian rate can fully offset the pollution-inflicted consumer welfare loss. With respect to the intersection E, the s^{o} and s^{*o} schedules partition the policy space into four distinct regions. The slopes of the ellipsoid W in each region are:

$$ds/ds^{*}\big|_{W} = -(dZ^{*}/ds^{*})(s^{*} - s^{*o})/(dZ/ds)(s - s^{o}). \qquad (22)$$

Since $dZ^{*}/ds^{*} < 0$ and $dZ/ds < 0$, the slopes in (22) depend on the initial position of s relative to s^{o} and s^{*} relative to s^{*o}. In region I (III) of Figure 1, the slopes of the welfare contours are negative because s > (<) s^{o} and s^{*} > (<) s^{*o} (i.e., pollution is under- (over) emitted in each country). In region II (IV), the slopes are positive because s > (<) s^{o} and s^{*} < (>) s^{*o} (i.e., pollution is under- (over) emitted in the home country, but is over- (under) emitted in the foreign country). To simplify the analysis, we assume for both countries identical demands, $E_Z = E_Z^{*}$, and the same proportions of transboundary pollution, $\alpha = \alpha^{*}$. Hence, by (20) and (21), we obtain $s^{oo} = s^{*oo}$, and these tax rates are represented by the points on the 45-degree ray.

4. POLLUTION TAX COORDINATION

We are now ready to examine the welfare effects of three alternative schedules of tax coordination: (i) The concertina rule, i.e. reducing the higher tax rate; (ii) uniform radial changes by adjusting the tax rates towards the optimum tax rates; and (iii) tax harmonization by moving the tax rates towards a weighted average rate. It is instructive to concentrate on ranking welfare among these three types of pollution tax reforms for the cases in which $s > s^*$, i.e. the area above the 45^o degree ray. The cases in which $s < s^*$ can be analogously examined.

4.1. Concertina Rule

Suppose that the initial situation is represented by point A located above the 45^o degree ray in region I or II of Figure 1. Given $s > s^*$, the concertina rule requires a small reduction in the higher tax rates from point A to point C, to compress the tax structure. According to the rule, the lower tax rate, which is the foreign pollution tax, is not allowed to change (i.e., $ds^* = 0$). From (19), this adjustment in s alone improves the home welfare by:

$$du = (dZ/ds)(s - s^o)ds, \tag{23}$$

where $d\mathrm{s} = -\beta(s - s^o) < 0$ and β is a positive fraction, $0 < \beta < 1$, denoting a small reduction of s towards s^o. The improvement in welfare is verifiable in Figure 1 by comparing the welfare levels associated with the two contours passing through points A and C, respectively.

4.2. Uniform Radial Rule

The concertina rule is quite restricted as it allows for the adjustment of only one policy instrument even though both policy variables deviate from their second-best optimal levels. Alternatively, both policy variables may be allowed to vary, such as in the case of radial changes or tax harmonization. So, we consider first uniform radial changes of pollution taxes. Let σ be a positive scalar and $\sigma < 1$; the redial rule can be specified as

$$ds = -\sigma(s - s^o), \tag{24}$$

$$ds^* = -\sigma(s^* - s^{*o}). \tag{25}$$

That is, both policy variables are adjusted towards their respective second-best levels. From (24) and (25), the relative adjustment of s to s^* can be expressed by

$$ds/ds^*\big|_R = (s - s^o)/(s^* - s^{*o}). \tag{26}$$

Since $s > s^o$ and $s^* > (<)\ s^{*o}$, the adjustment path AR is positively (negatively) sloped in region I (II) of Figure 1.

Under uniform radial adjustments, it is instructive to view the welfare change in two sequential steps: a small decrease in s from point A vertically towards s^o, say, at point C, then followed by a change in s^* horizontally towards s^{*o} at point R by (26). The welfare change in (19) can therefore be rewritten as

$$du = (dZ/ds)(s - s^o)ds + (dZ^*/ds^*))/(s^* - s^{*o})(\ \mathrm{d}s/ds^*\big|_R)ds \tag{27}$$

$$= -\sigma[(dZ/ds)(s - s^o)^2 + (dZ^*/ds^*)(s^* - s^{*o})^2] > 0, \tag{28}$$

which is unambiguously positive. Pollution tax reform by the uniform radial rule yields higher welfare. Note that the second term on the right-hand side of (27) is always positive; comparing (27) to (23), it is clear that uniform radial adjustments of a home pollution tax are welfare-superior to concertina changes when the magnitudes of ds are the same for both tax rules. This is also verifiable in Figure 1 by comparing the potato-shaped welfare contours passing through C and R respectively (not shown).

4.3. Harmonization Rule

Another popular tax reform is the harmonization of pollution taxes between two countries. Following Lahiri and Raimondos-Møller (1998), a harmonization rule can be defined by a small move towards an appropriate weighted average of the initial tax rates in the two countries. Let the weighted average of the initial taxes in the two countries be denoted by *h*:

$$h = \nu s + (1 - \nu)s^*, \tag{29}$$

where ν is the weight and is between 0 and 1. The choice of ν will be determined momentarily. The harmonization of pollution taxes can then be specified as

$$ds = \gamma(h - s) = - \gamma(1 - \nu)(s - s^*), \tag{30}$$

$$ds^* = \gamma(h - s^*) = \gamma\nu(s - s^*), \tag{31}$$

where γ is a positive adjustment coefficient. Using (30) and (31), we can obtain the change of *s* relative to s^* as

$$ds/ds^*|_H = - (1 - \nu)/\nu, \tag{32}$$

which is always negative. That is, under the rule of harmonization, the tax rates in the two countries will be adjusted, in the opposite direction. The higher tax rate *s* will be reduced, while the lower tax rate s^* will be increased.

Recall that the slopes of the representative welfare contour W in Figure 1 are $ds/ds^*|_W$ given earlier in (22). It is notable that the directional effect on welfare by tax harmonization is dependent on the value of $ds/ds^*|_H$ relative to $ds/ds^*|_W$. This can be seen by first considering an initial situation denoted by point A in region I. To improve home's welfare, the tax rates must be adjusted to locate to somewhere inside the ellipsoid W. That is, $ds/ds^*|_H < ds/ds^*|_W$ is necessary for welfare improvement under tax harmonization. Using (22) and (32), we can determine the weight, ν, which satisfies this relative slope condition, as follows:

$$\nu < (dZ/ds)(s - s^o)/[(dZ/ds)(s - s^o)/[(dZ/ds)(s - s^o) + (dZ^*/ds^*)(s^* - s^{*o})]. \tag{33}$$

By defining $\Delta = (s - s^o)/s$ and $\Delta^* = (s^* - s^{*o})/s^*$, we can choose a particular weight $\nu = (dZ/ds)\Delta/[(dZ/ds)\Delta + (dZ^*/ds^*)\Delta^*]$.[11] This weight satisfies (33), and then the changes in welfare in (19) become:

$$du = -\gamma(dZ/ds)(dZ^*/ds^*))\Delta\Delta^*(s - s^*)^2/[(dZ/ds)\Delta + (dZ^*/ds^*)\Delta^*], \qquad (34)$$

which is always positive.

On the other hand, if the initial situation is depicted by point A in region II, where $s > s^o$ and $s^* < s^{*o}$, then we have $ds/ds^*|_H < 0 < ds/ds^*|_W$, which yields $1 - ds/ds^*|_W < 1/\nu$. Hence, for any ν between 0 and 1, tax harmonization will improve welfare. Accordingly, the welfare changes in (19) become:

$$du = -\gamma(dZ/ds)(s - s^o)(s - s^*)[1 - \nu(1 - ds/ds^*|_W)] > 0. \qquad (35)$$

In Figure 1, the harmonization rule of pollution taxes is depicted by a movement from point A to point H, showing welfare improvement.

4.4. Ranking

Based on the above results, we can rank the welfare effects of the three schemes of pollution taxes. Using the decomposition method, the welfare change in (19) can be expressed by:

$$du = (dZ/ds)(s - s^o)ds + (dZ^*/ds^*)(s^* - s^{*o})(ds^*/ds)ds, \qquad (36)$$

where ds^*/ds in the second term represents the relative adjustments between s and s^* according to the concertina, radial, or harmonization rule.

As discussed earlier, $ds^*/ds|_C = 0$ under the concertina rule, while $ds^*/ds|_R = (s^* - s^{*o})/(s - s^o)$ for the radial rule. Hence, tax adjustments under the radial rule are always welfare-superior to the concertina rule. Nevertheless, welfare comparisons between the concertina (or the radial rule) and the harmonization rule are far less straightforward. Recall, from (32), $ds^*/ds|_H = - \nu/(1 - \nu) < 0$ under the harmonization rule, the harmonization rule is welfare-inferior (superior) to the concertina rule for the initial tax mix in region I (II) of Figure 1. Furthermore, in region II, the harmonization rule can be welfare-superior to the uniform radial rule, if the adjustment of s^* to s is relatively larger (i.e., $ds^*/ds|_H < ds^*/ds|_R$).

We summarize the above discussions in the following proposition:

Proposition: In a two-country model with international capital mobility, the welfare ranking of alternative reforms of pollution taxes is as follows:

(i) The concertina rule is welfare-inferior to the radial rule in both region I and II; the concertina rule is welfare-inferior (welfare-superior) to the harmonization rule in region II (I).

(ii) When the slope of the iso-welfare contour in the tax policy space is negative, the radial rule is welfare-superior to the harmonization rule.

5. CONCLUDING REMARKS

This paper examines the welfare effects of various coordination schemes of pollution taxes for economies connected via international capital flows. The transboundary pollution effect is incorporated in a simple two-country setting. Barring a full-fledged cooperation between two countries, three types of pollution tax coordinating rules are considered. In general, pollution tax coordination via the uniform radial adjustments of taxes is welfare-superior to the concertina rule of compressing tax structures. However, when there is a large disparity in initial tax rates between the two countries, the harmonization of pollution taxes may lead to a larger welfare improvement than the radial tax adjustments.

The comparison of welfare effects is conducted in terms of adjustments in pollution taxes only. Criteria other than taxes, such as reducing environmental damage to an acceptable level, maintaining the same level of trade volumes, capital inflows or government revenue, etc., can also be considered while determining the welfare effects of tax changes. Presumably, welfare rankings would be affected accordingly.

NOTES

1. During his trip to China in June 1998, Present Clinton spent a whole day in Guilin preaching about the importance of preserving environmental amenities for human beings. In addition to trade, foreign investment and human rights, environmental protection was a key issue on the agenda during his summit with China's leaders.
2. The concertina rule was announced and analyzed in Neary (1995, 1998). In the latter, Neary pointed out that the rule justified lowering high tariffs, but not raising low tariffs.
3. Pollution abatement is considered in Chao and Yu (1999). For a general treatment of tax-financing public goods, see Michael and Hatzipanayotou (1999).
4. See Copeland (1994) for details on the GDP function with pollution as a by-product.
5. Lahiri and Raimondos-Møller (1998) adopt a similar treatment.
6. This assumption is reflective of casual empirical observations. The manufacturing industry is generally more polluting than the service sector. The same assumption was adopted in Yu and Ingene (1982). Note that $\partial Z/\partial K = (\partial Z_X/\partial X)(\partial X/\partial K) + (\partial Z_Y/\partial Y)(\partial Y/\partial K) > 0$.
7. A conventional reason for investing in the foreign country is "tariff-jumping" aside from taking advantage of foreign cheap labor or land. See, for example, Jones (1967, 1987), and Beladi and Marjit (1992).
8. $\partial Z/\partial s = (\partial Z_X/\partial X)(\partial X/\partial s) + (\partial Z_Y/\partial Y)(\partial Y/\partial s) < 0$; pollution tax dampens pollution emission.
9. The home country cannot impose taxes on the transboundary spillover of foreign pollution, and vice versa.

10. For this sort of diagrammatic exposition involving two policy instruments, see Neary (1995).

11. This weight is suggested by Lahiri and Raimondos-Møller (1998).