Strategic Environmental Policy and International Trade in Asymmetric Oligopoly Markets

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Abstract

This paper examines optimal cooperative and non-cooperative environmental taxes for the case in which a polluting input is used to produce an internationally-traded finished product. The model allows for terms-of-trade effects under oligopoly and employs a general specification of the environmental damage function that encompasses special cases of local, global, and transboundary externalities. The model has several implications for public finance. For example, inefficiently high environmental taxes may be optimal for a net exporting country in non-cooperative circumstances, as the motive to shift rent by selecting an inefficiently low tax rate is countervailed by the incentive to shift the burden of the tax to foreign consumers. The findings identify the important role of asymmetric trade flows (denominated in both goods and pollution exchange) in determining optimal cooperative and non-cooperative tax policy under oligopoly.

Keywords: international trade, oligopoly, transboundary externality

1. Introduction

The potential use of taxes to internalize environmental externalities is a thoroughly investigated topic in all major industrialized countries. The OECD, the WTO, the European Commission, and other international organizations are currently evaluating possible environmental tax reforms and their effect on national and regional welfare and competitiveness (see Morgenstern, 1995; OECD, 1997). An obstacle to environmental tax reforms, however, is the inherent tension between facilitating freer international trade flows and allowing individual nations the authority to set unilateral, and perhaps non-harmonized, environmental policies.

It is clear that national environmental policies can undermine free trade. The idea that environmental policy can be used as a potential rent-shifting device in international settings has received considerable attention in the strategic trade literature. Recent contributions to this literature have been made by Conrad (1993), Barrett (1994), and Kennedy (1994), who consider environmental policy in a conventional strategic trade framework in which a polluting industry in each of two countries competes to export output to consumers in a third country.[1] The general outcome of these models is what has become known as the "environmental dumping" effect: national regulators have an incentive to set equilibrium taxes below the Pigouvian level in non-cooperative trade contexts. It may be optimal to set an environmental tax below marginal external damage under international oligopoly, because, in the sense of Brander and Spencer (1985), the incentive to internalize pollution damages is tempered by the ability of a country to shift rent. As Kennedy (1994) demonstrates, moreover, the incentive for environmental dumping is intensified under circumstances of transboundary pollution.

This paper extends the analysis of strategic environmental policy to consider market conditions characterized by various forms of international asymmetry. As a point of departure from conventional, symmetric models of strategic trade, we introduce domestic consumption within each production region and consider a general criterion for the distribution of the global consumer base. We also treat differences in production costs across countries and allow for alternative characterizations of transboundary pollution flows. The introduction of asymmetries dimensioned in consumption, production, and environmental damage flows allows us to assess the strategic trade implications of unbalanced trade in both goods and pollution.

Our analysis differs from its precursors in several important regards. Unlike the situation considered by Conrad (1993), we allow for a variety of environmental effects, including local, global, and transboundary externalities. The framework also differs from Kennedy (1994) in that we consider asymmetric pollution diffusion across countries, which permits, among other things, transboundary pollution situations with uni-directional system flows.[2] Finally, unlike Barrett (1994), we consider terms-of-trade effects and the commensurate dependence of environmental policy on both consumption- and production-distortion motivations.

The general representation of transboundary pollution we develop also clarifies an important issue in the conceptual approach to international pollution problems. In particular, the model allows for a distinction to be made between pollution effects that are rival or non-rival in nature, which underscores the question of whether environmental effects should be aggregated across countries in the manner of private or public goods.

Our findings can be organized into several main results. In the cooperative equilibrium, we find that the optimal tax policy under asymmetric-cost oligopoly does not involve harmonized tax rates across countries.[3] For all other forms of asymmetry, however, in particular for differences in the relative consumer base or in the share of global pollution damages across countries, we demonstrate that policy harmonization is optimal in the cooperative equilibrium. In the non-cooperative equilibrium, we find the selection of environmental policy to depend on three major influences: (i) a terms-of-trade effect; (ii) an imperfect competition effect; and (iii) a transboundary (or pollution leakage) effect. For transboundary externality problems, we find that each country has an incentive to set its tax rate below the cooperative level regardless of whether it is a net importer or exporter of pollution. We also show that the non-cooperative tax rate depends in an important fashion on a country's terms-of-trade. For a general distribution of the global consumer base, the find that the motivation of the domestic country to capture oligopoly rent for its firms is countervailed by the desire of the regulator to shift the burden of the tax to foreign consumers. As a result, a net exporting (importing) country has an incentive to set higher (lower) environmental taxes than would be efficient under cooperation.

2. The Model

Our study of international environmental regulations is framed by the following two-stage game.[4] In the first stage, the regulator in each country sets an emission tax on a polluting input and the tax rate set by each member of the trade union is revealed. In the second stage, firms treat the stage-one emission tax rates as parametric and play Cournot-Nash.

The model is comprised of a two-country trade union that satisfies the following properties. Consumers in the union have identical preferences, regardless of their country of origin, although the size of each consumer market (i.e., the number of consumers in each country) may differ. Firms within each country are homogeneous and produce a single non-differentiated product with a polluting input. Across countries, however, production costs and the number of firms in each country may differ, as would be the case for countries that implement different domestic labor policies or have different resource and technological endowments. Finally, intra-industry trade occurs between the two countries without transportation costs.[5]

Consider the problem of a firm in country i. Let $C_i(y_i, q(t_i))$ denote the cost function of a representative firm in country i, where y_i is output, t_i is the domestic emission tax set in the preliminary stage of the game, and $q(t_i)$ is the market price of the polluting input. The cost function is assumed to be twice continuously differentiable for the allowable range of y_i, increasing ($C_{y_i} > 0$) and convex ($C_{y_i y_i} > 0$).

The input market price is described by the linear function

$$q(t_i) = q_0 + t_i e, \tag{1}$$

where q_0 is the base price of the polluting input and e is an emissions coefficient that represents the quantity of emissions per unit of input. The value of e is taken to be identical for all firms; that is, we do not consider differences in abatement technology across countries. All other input prices are constant and are suppressed hereafter for notational simplicity.

With homogeneous consumers and no transportation costs between countries in the trade union, it follows that a single market price prevails. Let $P = P(Y)$ denote the price of the consumer good. World consumption, Y, is then specified as

$$Y = n_1 y_1 + n_2 y_2, \tag{2}$$

where y_1 and y_2 denote the output of a representative firm in country 1 and 2, respectively, and n_1 and n_2 are the number of firms that produce in each country.

The optimal output choice of a firm is characterized as the solution to

$$\operatorname*{Max}_{y_i} \pi_i = P(Y)y_i - C_i(y_i, q(t_i)), \tag{3}$$

which yields the following first-order condition:

$$P(Y) + y_i P'(Y) = C_{y_i}(y_i, q(t_i)). \tag{4}$$

Suppressing arguments, the second-order condition for a firm in country i is

$$2P' + y_i P'' < C_{y_i y_i}. \tag{5}$$

Making use of expressions (1)–(4) and the demand condition, $P = P(Y)$, it is possible to express individual firm output as a function of the tax set in each country, such that $y_1 = f(t_1, t_2)$ and $y_2 = g(t_1, t_2)$. Totally differentiating equations (4), it can be easily verified (subject to the standard Routh-Hurwicz conditions on second differentials) that

$$\frac{\partial y_i}{\partial t_i} < 0, \qquad \frac{\partial y_j}{\partial t_i} > 0, \quad i \neq j \tag{6}$$

$$\frac{\partial Y}{\partial t_i} < 0. \tag{7}$$

Expressions (6) and (7) complete the output stage of the model. We turn, next, to our specification of environmental damages.

3. Environmental Damage

Let $D_i = D(E_i)$ denote the environmental damage function, where E_i is the pollution level that contributes to damages in country i. For clarity, we consider the case in which damages increase with the level of pollution in each country, $D' > 0$, and marginal damage is constant, $D'' = 0$.[6]

We employ a general specification of environmental damages that encompasses various forms of transboundary pollution, including special cases of local, global and unidirectional externalities (as described below). Specifically, define E_i as

$$E_i = \sum_{j=1}^{N} s_i^j n_j e x_j \tag{8}$$

where $s_i^j \in (0, 1)$ is the share of total emissions produced in country j that contributes to environmental damage in country i, N is the number of countries, and x_j is the quantity of polluting inputs used by firms in country j. The specification of environmental damages in (8) is capable of application to externalities that are both rival and non-rival in their effects. The distinction between these types of effects turns out to be important for the global efficiency of environmental policy.

Consider, first, an externality that creates a purely rival external effect. For a rival effect, each unit of pollution that originates in country j creates external damage in either country i or country j, but not in both countries at once. Using the notation introduced in (8), the share of total pollution that originates in country j must satisfy $\sum_{i=1}^{N} s_i^j = 1$. Examples of a rival pollution effect include circumstances in which the pollutant becomes biologically fixed, such as would be the case for health effects associated with carbon monoxide or pesticide consumption.

At the other extreme, an externality may create a purely non-rival external effect. For a non-rival effect, each unit of pollution that originates in country j simultaneously creates external damage in all countries at once. The share of emission produced in country j in this case must satisfy $\sum_{i=1}^{N} s_i^j = N$; that is, $s_i^j = 1, \forall i$. There are numerous forms of externalities that create non-rival effects, of which global climate change from greenhouse gases is a leading example.

In our two-country model, it is possible to specify any externality or combination of externalities in (8) by choosing the appropriate elements of the set, $S = (s_1^1, s_1^2, s_2^2, s_2^1)$. In particular, expression (8) reduces to the case of a local externality, $D_i = D(n_i ex_i), \forall i$, when $S = (1, 0, 1, 0)$, and to a non-rival global externality, $D_i = D(n_i ex_i + n_j ex_j), \forall i$, when $S = (1, 1, 1, 1)$.[7] The pollution effect may also combine rival and non-rival components. For example, if γ denotes the share of pollution that is non-rival in nature, then $S = (1, \gamma, 1, \gamma)$.

Expression (8) also encompasses various forms of transboundary, or cross-border externalities. In particular, a unidirectional externality may arise through the flow of a river from one country to another, as in the case of U.S. agricultural production that contributes to salinity of the Colorado River at the Mexican border. Suppose, for the sake of clarity, that a chemical plant located in country 1 produces effluent associated with a purely rival external effect. If the effluent is released into a river that flows from country 1 to country 2, $D_1 = D(\beta n_1 ex_1)$, and $D_2 = D((1-\beta) n_1 ex_1 + n_2 ex_2)$, where the share of pollution that affects country 1, $\beta \in (0, 1)$, is determined by the distance of the plant to the border and the oxygen sag curve associated with the type of effluent released. In this case, $S = (\beta, 0, 1, 1-\beta)$.

4. Optimal Emission Taxes in the Cooperative Case

We now turn to the cooperative policy outcome.[8] In cases where environmental decisions are made at the trade union level, the problem is equivalent to one in which countries cooperatively determine emission taxes to maximize joint welfare. The joint welfare maximum is completely characterized as the solution to

$$\underset{t_i, t_j}{\text{Max}}\, W_C = \left[\int_0^Y P(U)\, dU - P(Y)Y\right] + \sum_i [n_i(P(Y)y_i - C_i(y_i, q(t_i)) + t_i ex_i) - D(E_i)], \tag{9}$$

where we have decomposed the problem into separate consumer surplus and producer surplus components for consistency with the non-cooperative formulation to follow. Using Shepard's Lemma, $C_q = x_i$, with (4), the first-order condition of (9) with respect to t_i is

$$\left[t_i - D'\left(s_i^i + s_j^i\right)\right] n_i ex_{y_i} \frac{\partial y_i}{\partial t_i} + \left[t_j - D'\left(s_j^j + s_i^j\right)\right] n_j ex_{y_j} \frac{\partial y_j}{\partial t_i} = P'\left(n_i y_i \frac{\partial y_i}{\partial t_i} + n_j y_j \frac{\partial y_j}{\partial t_i}\right), \tag{10}$$

where a similar condition holds for t_j. The regulator's optimal choice of the policy instruments, t_i^* and t_j^*, is found by solving these first-order conditions simultaneously.

From (12), the implicit cooperative tax-rule, $\hat{t}_i$, is given by

$$\hat{t}_i = \left(s_i^i + s_j^i\right) D' + \frac{\left(s_j^j + s_i^j\right) n_j e x_{y_j} \frac{\partial y_j}{\partial t_i}}{n_i e x_{y_i} \frac{\partial y_i}{\partial t_i}} D' - \frac{n_j t_j e x_{y_j} \frac{\partial y_j}{\partial t_i}}{n_i e x_{y_i} \frac{\partial y_i}{\partial t_i}} + \frac{P'\left(n_i y_i \frac{\partial y_i}{\partial t_i} + n_j y_j \frac{\partial y_j}{\partial t_i}\right)}{n_i e x_{y_i} \frac{\partial y_i}{\partial t_i}}, \tag{11}$$

where an equivalent expression holds for $\hat{t}_j$. The cooperative tax-rule (11) depends on the marginal damage associated with production in country i, plus three additional terms: a foreign pollution effect, a foreign tax effect, and an imperfect competition effect, respectively. The first term, the foreign pollution effect, is negative by (6), which implies that the optimal tax in country i decreases with the effect of the tax on foreign production and pollution. Because a tax in country i increases output in country j, the optimal tax in country i is set lower to account for the greater demand for polluting inputs, and the subsequent increase in pollution, by foreign firms. The second term, the foreign tax effect, is positive by (6), which indicates that the optimal tax increases with the level of the foreign tax. Finally, the last term, the imperfect competition effect, is negative by (6) and (7), which implies that the optimal domestic tax decreases with the degree of imperfect competition. This effect captures the tax adjustment associated with sub-optimal production levels under oligopoly.

Solving $\hat{t}_i$ and $\hat{t}_j$ simultaneously yields the equilibrium tax for country i:

$$t_i^* = \left(s_i^i + s_j^i\right) D' + \frac{y_i P'}{e x_{y_i}}. \tag{12}$$

The equilibrium tax for country i in (12) depends on two terms: (i) the total marginal damage of domestic production on the global environment; and (ii) the tax correction necessary to achieve efficient oligopoly pricing. Notice that the first term of (12) refines the optimal Pigouvian tax rule to encompass various cases of rival and non-rival externalities. In particular, the optimal tax reduces to the conventional Pigouvian tax ($t = D'$) under a rival externality, whereas, for a non-rival externality, the optimal tax rule is assessed according to the sum of marginal damages.[9] The cooperative tax rate is set to correct for two distortions with a single instrument, as the market is characterized both by over-production due to the negative externality and under-production due to the oligopoly structure. Consequently, the optimal cooperative policy levies a second-best tax below marginal external damage. Indeed, one can not even rule out the seemingly perverse outcome in which the second-best tax rate in (12) is negative (i.e., a subsidy), which corresponds with the observation originally made by Barnett (1980) that imperfectly competitive, but polluting firms may under-produce from the social perspective.

When the optimal tax rule is derived at the trade union level, producers in each country internalize both the share of domestic environmental damage (s_i^i) and the share of foreign environmental damage (s_j^i) associated with domestic production. Thus, the optimal tax in (12) does not take into account the location where damage occurs, but rather considers only responsibility for the damage.

The cooperative policy implication of each of the various forms of asymmetry in the model depends in an important fashion on the dimension in which trading countries differ. For the case of asymmetric production costs, the optimal cooperative tax in (12) is non-harmonized across countries; that is, a necessary condition for (4) to hold when $C_{y_i} \neq C_{y_j}$ is that $y_i^* \neq y_j^*$.

Conversely, for the case in which firms in each country have identical production costs, the optimal cooperative tax rate is harmonized across countries, $t_i^* = t_j^*$, even when other forms of asymmetry exist. For any specification of the consumer and producer distributions across countries, and for any specification of the transboundary pollution flow, a cooperative policy of tax harmonization is optimal whenever firms have equal production costs. This is because each firm releases an identical amount of emissions into the global environment when production costs are symmetric, $s_i^i + s_j^i = s_j^j + s_i^j$.

It is important to note, however, that the global welfare maximum may lie outside the core of the Nash equilibrium under asymmetric market conditions. In particular, under various specifications of the transboundary pollution flow the maximum global welfare solution is likely to result in higher welfare for one country and lower welfare for another. For example, consider the case of symmetric production costs and a unidirectional externality that satisfies $S = (0, 0, 1, 1)$. In this case, the optimal cooperative emissions tax is a harmonized policy that unambiguously reduces welfare in country 1 due to full exportation of external effects to country 2. Hence, the cooperative outcome may be feasible in multilateral agreements only to the extent that transfer payments are possible (see, e.g., Markusen, 1975; Hoel, 1991; and Chander and Tulkens, 1995) or when threats of economic sanctions are credible (Carraro and Siniscalco, 1998).

5. Optimal Emission Taxes in the Non-Cooperative Case

When regulatory authority is housed at the national level, each country views its optimal tax as the outcome of a non-cooperative game. Each country now considers only its own agents in the maximization of its domestic welfare. In conventional strategic trade model, consumption in producing countries is often suppressed for the interest of tractability; however, the following observation, which we prove in the appendix, allows consumer surplus to be conveniently incorporated in the domestic welfare calculation:

Observation. With globally homogeneous consumers, if country i's share of the consumer population is α_i, then consumer surplus in country i, CS_i, satisfies $CS_i = \alpha_i CS$, where CS is consumer surplus derived from global demand.

Because the international market is characterized by homogeneous consumers and a single market price, a domestic input tax that changes the production cost of domestic firms affects all consumers in the trade union equally through the equilibrium adjustment in the international market price. Hence, following a change in tax policy in one country, the change in consumer surplus is identical across countries on a per domestic consumer basis.[10] This observation allows a convenient interpretation of the terms-of-trade of country i, which can now be written as the net trade balance, $\alpha_i Y - n_i y_i$, where $\alpha_i Y$ is domestic consumption and $n_i y_i$ is domestic production.

The objective function of a national regulator can now be expressed as

$$\underset{t_i}{\text{Max}}\, W_i = \alpha_i \left[\int_0^Y P(U)\, dU - P(Y)Y \right] + n_i [P(Y) y_i - C_i(y_i, q(t_i))] - D(E_i) + t_i n_i e x_i. \tag{13}$$

By (4) and Shephard's Lemma ($C_q = x_i$), the first-order condition yields

$$\hat{t}_i = s_i^i D' + \frac{(\alpha_i Y - n_i y_i)\frac{\partial Y}{\partial t_i} P'}{n_i e x_{y_i} \frac{\partial y_i}{\partial t_i}} + \frac{n_j x_{y_j} \frac{\partial y_j}{\partial t_i}}{n_i x_{y_i} \frac{\partial y_i}{\partial t_i}} s_i^j D' + \frac{y_i P'}{e x_{y_i}}. \tag{14}$$

Expression (14) is the implicit reaction function of country i and describes the structure of the equilibrium tax.[11] In (14), $s_i^i D'$ is the share of marginal damages incurred in country i from its domestic production, which we henceforth refer to as the generalized Pigouvian tax level (GPT). In the polar cases of a local externality or a non-rival externality, $s_i^i D' = D'$, and the GPT corresponds with a conventional Pigouvian tax.

It is important to note that the conventional Pigouvian tax rate may or may not be efficient. In (14), a national regulator considers only domestic marginal damage, $s_i^i D'$, rather than the global marginal damage induced by domestic production, $(s_i^i + s_j^i)D'$, that appears in the optimal cooperative tax (11), terms that coincide only in the case of a local externality.

In general, the optimal tax set by a national regulator is equal to the GPT plus three additional terms that denote, respectively, a terms-of-trade effect, a transboundary pollution effect, and an imperfect competition effect. For clarity, we consider each effect in turn.

Consider, first, the case of balanced trade ($\alpha_i Y = n_i y_i$) and no transboundary effects ($s_j^i = 0$). In this case, the optimal tax modifies the GPT only by the last term in (14), the imperfect competition effect, so that the optimal cooperative and non-cooperative tax rates coincide. This leads to an observation that is often misunderstood in the literature: a country that attempts to correct two distortions with a single instrument does not necessarily practice eco-dumping when the tax is set below the GPT level. Indeed, the reduction in the non-cooperative tax rate under balanced trade is exactly that which is necessary to achieve efficient pricing under oligopoly from a global welfare perspective.

Consider next the case of balanced trade with transboundary pollution effects. In this case, the transboundary effect adjusts the optimal domestic tax rate downward to account for the ineffectiveness of unilateral tax policy to internalize global environmental damages. This term reflects a pollution crowding-out effect. By (6), the decrease in domestic production under a domestic tax is at least partially offset by an increase in foreign production (and pollution), and, consequently, under any form of transboundary pollution effect, the GPT is discounted to prevent increased foreign pollution inflows from offsetting the domestic welfare gain. In the non-cooperative case, transboundary damages result in non-harmonized tax rates across countries when $s_i^j \neq s_j^i$, i.e., whenever the trade balance in pollution emissions is non-zero. In general, the net importer of pollution sets a lower tax than the net exporter as an incentive to increase domestic production, but, in equilibrium, both countries set taxes below the GPT level.

Finally, consider the terms-of-trade effect. By (8) and (9), the sign of the terms-of-trade effect is positive whenever country i is a net exporter, $\alpha_i Y - n_i y_i < 0$, and negative when country i is a net importer. The effect is similar to that identified in the capital tax literature as a negative fiscal externality from tax exportation (see, e.g., Dixit, 1985; Burgess, 1988). A net exporting country has an incentive to set a tax greater than the GPT level, because a portion of the tax is shifted into price where it disproportionately affects foreign consumers. Indeed, in the extreme case in which there is no consumer base in country i, a situation that

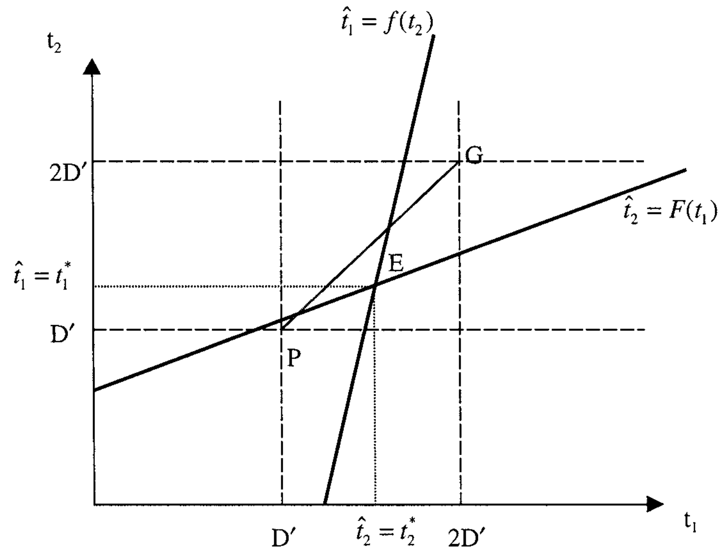

Figure 1. Tax equilibrium under asymmetry (2-country case).

corresponds to conditions under a third country assumption, the optimal non-cooperative tax rate is adjusted upwards relative to that in the cooperative case.[12]

It is helpful to consider the terms-of-trade effect in some detail. Suppose there are no transboundary pollution effects and all consumption takes place within the two producing countries. Suppose further, with no loss of generality, that that country 1 is the net exporter. In this case, the model assumptions are sufficiently general so that the slopes of the reaction curves are of ambiguous signs. Figure 1 shows the case for which reaction functions are positively sloped, which corresponds with the case in which taxes are strategic complements. In the figure, the cooperative solution to a non-rival externality problem is at point G, while the cooperative optimum in the case of a rival externality is at point P. Thus, the segment $[P, G]$ represents all the possible cooperative solutions in our model. In the non-cooperative case, when country 2 is at the zero tax position, $t_2 = 0$, country 1 sets its tax above the GPT level, because of the positive terms-of-trade effect. Similarly, when country 1 is at the zero tax position, $t_1 = 0$, country 2 sets its tax below the GPT level.

Next, suppose that both countries simultaneously engage in a green tax reform (i.e., $t_1, t_2 > 0$). In this case, the imposition of a tax by country j improves the trade position of country i through the trade balance effect, as

$$\frac{\partial(\alpha_i Y - n_i y_i)}{\partial t_i} < 0, \tag{15}$$

where the inequality in (15) holds by (6) and (7). The implication of (15) is that each country has an incentive to raise the tax above the level they would have chosen in the case of unilateral taxation; hence, the reaction functions slope upward. At the non-cooperative equilibrium point in Figure 1, E, country 1 sets a tax above the GPT level, whereas country 2 may or may not. This result contrasts with the conventional result of symmetric Cournot-Nash duopoly models, in which all countries set taxes equal to or below the GPT level. Here, environmental dumping is not a universal outcome under duopoly, as a net-exporting country may set a tax that is higher than in the cooperative case.

We now turn to the case in which multiple effects influence the optimal domestic tax policy in (14). In general, the range of circumstances in which an exporting country sets a tax greater than the GPT level is now reduced, as the imperfect competition effect and transboundary effect provide opposing incentives against the positive terms-of-trade effect. In this case, the critical value of each reaction function is an important indicator of whether the equilibrium tax in the country is ultimately set above or below the GPT level. More precisely, an intercept above the conventional Pigouvian tax level is a sufficient condition for the equilibrium tax to exceed D' when taxes are strategic complements. For this reason, in an imperfectly competitive industry with an arbitrarily small terms-of-trade effect, the equilibrium tax of each country lies below the GPT level, a standard finding in analyses of symmetric Cournot-Nash equilibria.

6. Concluding Remarks

The paper discussed optimal environmental tax policies for a general class of asymmetric international equilibria. A principle finding is that differences in industry size and production costs and/or the distribution of consumers across countries have profound effects on the calculation of the optimal tax and the resulting tax revenue. The optimal cooperative tax was found to depend on marginal environmental damages from domestic production on the global environment as well as on an imperfect competition effect, such that asymmetries in production costs lead to circumstances in which harmonization of taxes across countries is sub-optimal. In contrast, asymmetries across countries dimensioned in the number of consumers or in the distribution of transboundary pollution damages favor cooperative policies of tax harmonization.

The optimal non-cooperative tax was shown to depend on three effects: a terms-of-trade effect, a transboundary pollution effect, and an imperfect competition effect. For certain values of the market parameters, the optimal tax for a net exporting nation exceeded the Pigouvian tax level regardless of the incentive of a domestic regulator to shift rent in the international market.

When trade balances are non-zero, environmental policy distortions occur in a trade union that establishes environmental policy in a non-cooperative setting. Lax environmental taxes that result in environmental dumping by all trading countries are more likely to occur for externalities that are associated with non-rival and transboundary forms of pollution effects. However, even in such circumstances, environmental dumping is not a universal outcome; for various values of the market parameters the optimal policy for a net exporting nation is to set an inefficiently high tax.

The model suggests several directions for future research. In the non-cooperative case, an implication of the model is that a national regulator is more likely to improve domestic welfare by setting emission taxes in net exporting sectors of the economy than in net importing sectors, which points toward future empirical investigation into the relationship between national or regional trade balances and environmental taxation. The fact that the optimal tax rate is higher for a net exporter than for a net importer also has interesting implications for what has become known as the "pollution haven" hypothesis: the idea that capital investment in "dirty" industries may flow to countries with lax environmental regulations. Such an outcome, which is a theoretical prediction of many models with endogenous firm location, has for the most part lacked empirical corroboration. In a dynamic formulation of the present model, in which the optimal non-cooperative tax is an endogenous function of the trade balance, such a relocation and/or investment pattern is likely to be dynamically inconsistent. If, following the investment and relocation decisions of firms, the optimal environmental tax rate increases with the migration of polluting industries through positive changes in terms-of-trade, "pollution havens" would be unlikely to persist.

Appendix

This appendix contains the proof of our observation. Define individual utility such that $U = U(y) + m$, where y is the quantity of a consumption good that is produced using a polluting input, and m is the numeraire. Individual consumer surplus is

$$cs = U_y(y) - Py = \int_0^y P_i(\tilde{y})\, d\tilde{y} - Py,$$

where $P_i(y)$ is the inverse demand of individual i. Households have identical utility. Hence, when one household is willing to buy y units of a good at price P, n households are willing to buy ny units of a good at price P, which implies

$$P_i(y) = P(ny) = P(Y),$$

where $P(Y)$ is global inverse demand, which in this case corresponds to the trade union. Assuming there are n homogeneous individuals in the union, global consumer surplus is

$$CS \equiv n(cs) = n\left[\int_0^y P_i(\tilde{y})\, d\tilde{y} - Py\right],$$

Also, global consumer surplus can be expressed as the area above the price line and below the world demand curve,

$$CS = \int_0^Y P(\tilde{Y})\, d\tilde{Y} - PY$$

Let denote the share of consumers in the trade union that are located in country i. Equating (1) and (2), consumer surplus in country i satisfies

$$CS_i = \alpha_i n(cs) = \alpha_i\left[\int_0^Y P(\tilde{Y})\, d\tilde{Y} - PY\right] = \alpha_i CS$$

which completes the proof.

Notes

1. These papers consider strategic environmental policy with exogenous firm location. International environmental policy has also been examined under conditions of endogenous location. For example, Rauscher (1995) analyses environmental policy in a context where the level of regulation influences the location of polluting industries.
2. In many transboundary pollution problems, the shared environmental medium may not be well-mixed. For example, jet streams and river currents often flow in a single direction across national boundaries, which creates a situation of unilateral inflow (outflow) of air and water pollutants.
3. Ulph (1998) also finds that environmental tax harmonization can have adverse welfare consequences; however, his result depends on different environmental damage costs across countries, a situation not considered here.
4. The model is presented as a partial equilibrium analysis, but, implicitly, we are assuming that trade balance is achieved behind the scenes by the existence of another traded good produced by a purely competitive industry.
5. Currently, most world trade is characterized by intra-industry trade flows, especially in high-income countries (see, e.g., Ethier (1995, pp. 33–36)).
6. Constant marginal damages are imposed here for expositional convenience, as this allows global damages to be expressed in terms of the shares of pollution produced and consumed in each country. Sufficient conditions to make this interpretation are $D'(0) = 0$ and $D'''(.) = 0$, from which derives the property that $D'(x + y) = D'(x) + D'(y)$. With a more general specification of the environmental damage function, the qualitative implication of each effect identified in this paper would remain unchanged, although new terms would appear in the tax calculations resulting from non-convexities in the global damage function.
7. We conceive of a local externality here as a rival externality that occurs entirely in the source country. That is, a rival effect is a necessary, but not a sufficient, condition for a local externality.
8. In both the cooperative and non-cooperative cases, we consider circumstances in which lump sum transfers are possible. As a referee points out, extension of the model to second-best policy considerations would open up interesting possibilities for a double dividend effect to exist.
9. For an externality with both rival and non-rival effects, the optimal tax would satisfy $D' < t < 2D'$.
10. As an editor of the *Journal* points out, the usefulness of our observation can be seen through comparison to the situation facing a cartel. In the basic cartel problem, the share of aggregate industry profit of each firm is an endogenous function of the choice variables. Here, the share of domestic consumers (and the associated share of consumer surplus) is exogenous to the regulator's decision, which allows the share of global consumer surplus to be substituted for the domestic surplus measure prior to maximization. If the policy under consideration here was a tax on domestic sales, as opposed to an input tax, then the policy impact to consumers would depend on the country of origin, and, consequently, consumer surplus shares would be endogenous as in the case of cartel firms.
11. As in Conrad (1996), it is necessary to study the optimal tax structure without explicitly solving for the equilibrium taxes. However, because the equilibrium point is an intersection of two reaction functions, the implicit structure of (14) is preserved at the equilibrium point. Throughout, we refer to $\hat{t}_i$ as the optimal tax, but the reader should keep this distinction in mind.
12. In this case, the tax rate in (14) is comprised of the GPT, plus two additional terms that represent a decomposition of the conventional 'rent-shifting' effect into an extreme positive correction for terms-of-trade and a well-known subsidization rule for efficient pricing under oligopoly.

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