Chapter 9 ENVIRONMENTAL POLICY AND TRADE LIBERALIZATION UNDER IMPERFECT COMPETITION

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ABSTRACT

This chapter examines the strategic incentives to distort pollution taxes in open economies with imperfect competition. I first examine a world economy in which a pollution tax is the only instrument available. The associated free-trading equilibrium pollution taxes are distorted away from the globally efficient taxes by three separate effects: the usual transboundary externality effect, a rent capture effect and a pollution-shifting effect. I then examine a setting in which both a pollution tax and a production subsidy are available. The equilibrium in which taxes and subsidies are set non-cooperatively is globally efficient in the absence of transboundary pollution. When pollution is at least partly transboundary the equilibrium subsidy is positively distorted by a strategic incentive to capture foreign rents and the equilibrium tax is negatively distorted by the usual transboundary externality. Finally, I examine a restricted equilibrium in which countries agree not to use subsidies for trade-related goals. In the absence of transboundary pollution the pre- and post agreement equilibria coincide and both are efficient. When pollution is transboundary the pollution tax takes on the strategic trade role previously played by the subsidy and is negatively distorted relative to the pre-agreement equilibrium and relative to the globally efficient solution.

9.1 INTRODUCTION

One of the most contentious issues raised in the debate over the North American Free Trade Agreement (NAFTA) was the likely impact that trade liberalization would have on environmental quality. Opponents of the deal argued that the United States and Canada would be forced to weaken their environmental standards in an attempt to compete with Mexico. Proponents of NAFTA counter-argued that freer trade would make Mexicans richer and thus more demanding of higher environmental quality. Free trade would therefore lead to higher environmental standards in North America. This type of debate is likely to arise increasingly around the world. The

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latest round of GATT talks for the most part excluded environmental issues, but the environment is almost surely going to be a sticking point in the next round of talks. Similarly, any move towards a Pacific free-trade zone or an expansion of the European Union to include Eastern European countries will likely face resistance based at least in part on fears about the impact of freer trade on environmental quality. Moreover, concerns about trade and the environment are not limited to instances of trade between rich countries and relatively poor countries. The same sort of concerns were raised in the debate over the Canada-United States free trade agreement (the precursor to the NAFTA) and the issue continues to generate disputes within the existing European Union.

There is undoubtedly some truth in both sides of the argument over trade and the environment. Gains from trade will make countries richer and this may tend to produce higher environmental standards (although possibly still with lower environmental quality in the aggregate).[2] On the other hand, there surely exist strategic incentives to relax environmental standards for trade-related goals. Which effect will dominate in the end is an empirical question; no amount of theory is likely to resolve this debate definitively. However, there is a clear role for theoretical analysis in clarifying the debate and focusing attention on key aspects of the relationship between trade liberalization and environmental policy.

The purpose of this chapter is to provide an analysis of the strategic incentives to distort environmental policy in open economies in the presence of imperfect competition. The framework for the analysis has three main features. First, global trade is driven by imperfect competition among producers. Trade occurs between countries because the multinational firms based in those countries find it profitable to sell in foreign markets. This oligopolistic framework allows me to abstract from the traditional bases for trade (such as comparative advantage) and focus on strategic effects. Second, the tax choice game between competing countries is modeled explicitly. This permits an examination of strategic policy distortions in equilibrium. Third, the model allows for transboundary pollution. A single parameter captures the extent to which pollution is transboundary and this permits an examination of a continuum of cases, from purely local pollution to perfectly transboundary pollution. The chapter has two main parts. In the first part I examine a world in which a pollution tax is the only instrument available. I compare the free-trading Nash equilibrium taxes with the globally efficient taxes in this setting. My purpose is to highlight the nature of the strategic distortions to pollution taxes that may arise in

[2] The higher world output associated with freer trade may produce more pollution even if production techniques become cleaner.

free-trading economies. The second part of the chapter extends consideration to a setting in which both pollution taxes and production subsidies are available. I focus on production subsidies because the issue of "unfair" production subsidies has created so much conflict in recent trade talks surrounding both the GATT and the NAFTA.[3] Production subsidies can have a legitimate role in an imperfectly competitive setting as a measure to correct for the associated under-production problem. However, there exist incentives to misuse (distort) production subsidies for trade-related goals. I examine these incentives in the context of a non-cooperative Nash equilibrium in pollution taxes and unrestricted subsidies. I then examine the implications of a trade liberalization agreement that prohibits the use of subsidies for trade-related goals. I focus on the implications for equilibrium pollution taxes.

The rest of the chapter is organized as follows. Section 9.2 presents the model. Section 9.3 compares the Nash equilibrium taxes with the globally efficient taxes when a pollution tax is the only instrument available. Section 9.4 then derives the Nash equilibrium in pollution taxes and unrestricted subsidies. Section 9.5 examines the Nash equilibrium under a trade-liberalization agreement. Section 9.6 concludes. For a review of related literature the reader is referred to Kennedy (1994).

9.2 THE MODEL

There are two identical countries each producing a polluting homogeneous good x. Production in each country occurs within a symmetric oligopolistic industry with n firms. The entry of new firms is prevented by some sunk cost already incurred by established firms. The 2n firms compete openly in the two markets. Marginal production cost is constant and equal to the chosen level of pollution abatement θ. Output by a representative firm in country i is denoted y_i. This output is divided between home country sales y_i^H and foreign country sales y_i^F. Total production by country i firms is denoted Y_i. Production in country i generates pollution $Z_i=(Y_i/\theta_i)$ in country i, and a fraction $\alpha\in[0,1]$ of this pollution also affects the other country. If $\alpha=0$ then pollution is purely local. If $\alpha=1$ then pollution is perfectly transboundary.[4] Pollution generates environmental damage in country i according to the function $e_i=e(Z_i+\alpha Z_{-i})$ where a "-i" subscript denotes the other country. Damage is increasing and convex in pollution. The inverse demand for x in each country is $p(X_i)$ where X_i

[3] For example, alleged subsidies in aircraft and automobile manufacturing were a major source of difficulty in the last round of GATT talks. Similarly, the issue of subsidies in timber production continues to generate considerable conflict between the United States and Canada.

[4] Note that the degree to which pollution is transboundary is entirely independent of the extent of trade. It is determined only by chemical and geographical factors.

is the amount sold in country i.[5] The notational distinction between X_i and Y_i is needed to allow for imports and exports. Welfare in each country is measured as the sum of consumer surplus and profit, less environmental damage. Country i levies a tax τ_i on pollution and pays a subsidy s_i on domestic production.

9.3 EQUILIBRIUM WITHOUT SUBSIDIES

In this section I compare the Nash equilibrium taxes with the globally efficient taxes when a pollution tax is the only instrument available. This section is based on Kennedy (1994) and the reader is referred to that source for a more extensive analysis.[6]

9.3.1 Efficiency

It should be noted at the outset that the efficient taxes I present here are second-best. The first-best solution can only be achieved with the use of a pollution tax *and* a production subsidy to address the under-production associated with the imperfect competition. I consider the role of the production subsidy in section 9.4.

The planning problem is to set a uniform tax on pollution to maximize the welfare of a representative country, given the equilibrium behaviour of firms.[7] Welfare is defined as the sum of consumer surplus and profit, less environmental damage. The first-order condition to this planning problem is

$$(p - t)(\partial X/\partial t) - X = (1+\alpha)e'[t(\partial X/\partial t) - X]t^2 \qquad (9.1)$$

where $e' \equiv \partial e/\partial Z$ and $t \equiv \tau^{1/2}$. The LHS is marginal abatement cost. The RHS is marginal global damage. Note that marginal abatement cost has two components: the first term reflects the welfare cost of the reduced output associated with the tax; the second term reflects the increased marginal cost of production.

[5] Note that this inverse demand function implies the absence of income effects.

[6] Related papers of interest include Barrett (1994), Cumberland (1979), Markusen et.al. (1993), Mintz and Tulkens (1986), Oates and Schwab (1988), Ulph (1992) and Wildason (1988).

[7] It is sufficient to consider a uniform tax because countries are identical, and because damage is strictly convex in pollution.

In a perfectly competitive market in which price is equal to the tax-inclusive marginal cost, equation (9.1) would reduce to $t^2 = e'(1+\alpha)$ or $\tau = e'(1+\alpha)$. That is, the tax would be set equal to marginal damage; this is the standard Pigouvian rule. In contrast, in an imperfectly competitive equilibrium, price is distorted above social marginal cost, and so there is a strictly positive welfare cost associated with a reduction in output. This means that the efficient tax is set below marginal damage.[8] This result can be seen more clearly by rewriting (9.1) as

$$(t - e'(1+\alpha)/t) = Xp'\epsilon/(\epsilon-1)2n \tag{9.2}$$

where $\epsilon \equiv (\partial Y/\partial t)t/Y$ is the elasticity of equilibrium output with respect to t. The RHS of (9.2) is negative for finite n so the optimal t^2 is less than $e'(1+\alpha)$.

9.3.2 Nash equilibrium

The governments in both countries will choose their tax rates knowing that the choice of the domestic tax rate will affect the world price and therefore affect production both in the home country and in the foreign country. This is the source of the strategic interaction between the two countries. Each country is able to affect the aggregate reaction function for the firms based there by changing its tax rate. Manipulation of the reaction function in turn has the potential to alter the equilibrium aggregate production level and the equilibrium mix of production. Each country has an incentive to exploit this to its advantage.

The policy problem for each national government is to set its tax rate to maximize domestic welfare, given the equilibrium behaviour of firms and given the tax rate of the other country. The game between governments gives rise to the following symmetric equilibrium condition:

$$(t - e'/t) = Xp'\epsilon_i/(\epsilon_i-1)2n + \alpha e'\epsilon_{-i}/(\epsilon_i-1)t \tag{9.3}$$

where $\epsilon_i \equiv (\partial Y_i/\partial t_i)t_i/Y_i$ and $\epsilon_{-i} \equiv (\partial Y_{-i}/\partial t_i)t_i/Y_{-i}$. Comparing (9.3) with the efficiency condition in (9.2) clearly indicates that the Nash equilibrium will generally not coincide with the globally efficient solution. At the globally efficient taxes there is an incentive for each country to deviate.

The equilibrium incentive to deviate from the efficient tax can be thought of as comprising three separate effects. The first is the usual *transboundary externality effect*.

[8] For an analogous result in the monopoly case see Barnett (1980) and Lee (1975).

Each country ignores the impact of the pollution created within their boundaries on the environment outside their boundaries, and tax rates therefore tend to be set lower than is globally efficient.[9] If pollution is purely local then this effect vanishes. It is important to stress that this source of inefficiency does not stem from the openness of the economies per se. The same transboundary pollution problem would persist in a non-cooperative equilibrium between closed economies.

The second effect is a *rent capture effect*. A unilateral change in a country's tax rate has a bigger effect on equilibrium domestic production than it does on equilibrium domestic consumption (since foreign costs are not affected). The difference is reflected in a change in net exports. A unilateral reduction in the domestic tax rate therefore has the potential to raise net exports and thereby permit the capture of rent from foreigners. This rent comprises the profits from net exports plus the tax revenue earned on net exports. Both contribute directly to the domestic surplus. The rent capture effect is negative; that is, it tends to negatively distort the equilibrium tax rates from their efficient levels. The reason is as follows. The pollution tax raises the marginal cost of production for firms in the taxing country and so adversely affects the ability of those firms to compete for net exports. Each country attempts to gain a competitive advantage over its trading partner by reducing the tax. Note that this distortion is a purely strategic effect arising directly from the openness of the economies. Moreover, no rents are actually captured in equilibrium because both countries act symmetrically, but tax rates are distorted nonetheless. The distortions are therefore purely destructive.

The third effect is a *pollution shifting* effect and it works in the opposite direction to the rent capture effect. A unilateral tax increase tends to shift production and its associated pollution to the other country. It is therefore possible to achieve a reduction in domestic pollution with a lower adverse impact on domestic consumption than would be possible in a closed economy. Of course the strategy is potentially effective only if pollution is not perfectly transboundary. If pollution is perfectly transboundary then shifting production to the other country provides no relief for the domestic environment. In that case the pollution shifting effect vanishes. When pollution is less than perfectly transboundary the pollution shifting effect is strictly positive; it tends to positively distort the equilibrium tax rates away from their efficient levels. The effect is strongest when pollution is purely local because none of the shifted pollution returns to damage the domestic environment. Like the rent capture effect, the pollution shifting effect is a purely strategic effect that arises

[9] It should be noted that the relevant "boundaries" here are not necessarily geographical boundaries. The relevant boundaries are the boundaries of the interests of domestic residents.

directly from the openness of the economies. It is also purely destructive. Pollution shifting yields no benefits in equilibrium because each country acts symmetrically, but equilibrium taxes are nonetheless distorted in the attempt to shift pollution.

The rent capture effect and the pollution shifting effect operate in opposite directions, so the net strategic effect could potentially be either positive or negative. It turns out that the rent capture effect dominates the pollution shifting effect except in the case of perfect competition with no transboundary pollution.[10] In that special case the two effects are exactly offsetting. The reason is the following. Diverting production to the foreign country through a unilateral increase in the tax rate has a cost in foregone rent, and a benefit in shifted pollution. Under perfect competition the foregone rent is simply the tax revenue. When pollution is purely local the private benefit from shifting pollution is equal to the domestic social benefit of reducing production. This cost and benefit are necessarily equal at a social optimum implemented by a Pigouvian tax. Note that the usual transboundary externality also vanishes when pollution is purely local so the Nash equilibrium is efficient in this special case. In all other cases the Nash equilibrium is inefficient and pollution taxes are too low relative to the global optimum. In particular, imperfect competition leads to a strictly negative net strategic effect, even when pollution is purely local: the rent captured under imperfect competition exceeds the tax revenue, and so must also exceed the benefits from shifting pollution. When pollution is at least partly transboundary then the benefits of shifting pollution are even smaller and so the rent capture effect must continue to dominate. This net negative effect reinforces the usual transboundary externality giving rise to equilibrium taxes that are lower than is globally efficient.[11]

9.4 EQUILIBRIUM WITH SUBSIDIES

In this section I introduce production subsidies. I examine the Nash equilibrium taxes and subsidies before the introduction of any agreement to restrict the use of subsidies. It will be useful to begin with a characterization of the globally efficient taxes and subsidies.

[10] See Kennedy (1994) for the proof.

[11] The net strategic effect also tends to compound the environmental damage associated with the usual transboundary externality because the lower taxes lead to higher output.

9.4.1 Efficiency

The tendency towards under-production in an industry characterized by imperfect competition implies a potential role for a production subsidy in implementing an efficient allocation. The actual role for a production subsidy depends on the underlying reason for the imperfect competition and on whether or not direct competition policy can better enhance competition. I abstract from this issue of choosing between alternative policies and simply assume that a production subsidy is the instrument of choice for boosting production. This is justified by the fact that production subsidies are widely observed in real economies and have been one of the main items of concern in recent world trade negotiations.

The planning problem is to set the taxes and subsidies to maximize global welfare. The first step towards solving this problem is to characterize the industry equilibrium when all firms face the same tax and subsidy rates.

Industry equilibrium

The problem for the representative firm based in country i is

$$\max_{y_i^H, y_i^F, \theta_i} p(X_i)y_i^H + p(X_{-i})y_i^F - (\theta_i - s)y_i - \tau(y_i/\theta_i) \qquad (9.4)$$

where τ is the tax rate on pollution and s is the production subsidy. Demand conditions are identical in the two markets so the firm will sell half its output in each country. The conditions for profit-maximization therefore reduce to

$$p + s + yp'/2 = (\theta_i + \tau/\theta_i) \qquad (9.5)$$

$$\theta^2_i = \tau \qquad (9.6)$$

where the country subscripts have been omitted because τ and s are independent of i, and where $p \equiv p(X)$ and $p' \equiv p'(X)$. The second-order conditions are satisfied if $3p' + yp'' < 0$. This condition is henceforth assumed. Recalling that $t \equiv \tau^{1/2}$, these conditions can be rewritten as $\theta = t$ and

$$p + s + yp'/2 = 2t \qquad (9.7)$$

where 2t is the after-tax marginal cost faced by the firm. The Nash equilibrium can be found by multiplying (9.7) by 2n and setting $ny = X$ to obtain

$$2np + 2ns + p'X - 4nt = 0 \tag{9.8}$$

The stability of this equilibrium is guaranteed by the constancy of marginal cost and the second-order conditions for (9.4). The effects of symmetric policy changes on domestic consumption in both countries can be derived from (9.8):

$$\partial X/\partial t = 4n/[(2n+1)p' + Xp''] \tag{9.9}$$

$$\partial X/\partial s = -2n/[(2n+1)p' + Xp''] \tag{9.10}$$

It follows from the second-order conditions for profit-maximization that $\partial X/\partial t < 0$ and $\partial X/\partial s > 0$.

The planning problem

The planning problem can be formulated as maximizing the welfare of a representative country, given the equilibrium behaviour of firms embodied in (9.9) and (9.10). Throughout I assume that subsidies can be financed by lump-sum taxes and that pollution tax revenues are returned to citizens in a lump-sum fashion. I abstract from any income effects associated with this intervention. Welfare is defined as the sum of consumer surplus and profits (gross of tax payments and net of subsidy receipts), less environmental damage:

$$\begin{aligned} W &= [\int_0^X p(\tilde{X})d\tilde{X} - pX] + (pX - 2tX + \tau X/t) \\ &\qquad - e((1+\alpha)X/t) \\ &= [\int_0^X p(\tilde{X})d\tilde{X} - tX - e((1+\alpha)X/t) \end{aligned} \tag{9.11}$$

since tax revenue is $\tau X/t = tX$. The second-order condition for the problem in (9.4) and the convexity of e(.) are sufficient to ensure that W is concave in t and s. The first-order conditions to the planning problem are

$$(p - t)(\partial X/\partial t) - X = (1+\alpha)e'[t(\partial X/\partial t) - X]/t^2 \tag{9.12}$$

$$(p - t)(\partial X/\partial s) = (1+\alpha)e'(\partial X/\partial s)/t \tag{9.13}$$

Joint solution of (9.12) and (9.13) yields conditions for the efficient tax and subsidy rates respectively:

$$t^2 = (1+\alpha)e' \tag{9.14}$$

$$p = t + (1+\alpha)e'/t \tag{9.15}$$

Consider condition (9.15) first. This condition states that the optimal subsidy is chosen to equate price with the marginal global social cost of production. Marginal global social cost comprises the private marginal cost of production t (since $\theta=t$ in equilibrium), plus the marginal cost of global environmental damage. The planner uses the subsidy to correct for the inefficiency associated with under-production due to imperfect competition.

Now consider condition (9.14). This condition states that the pollution tax is optimally set equal to marginal global environmental damage. This is the standard Pigouvian taxing rule. This result contrasts with the planning solution in section 9.3 where a subsidy is unavailable. In that case the pollution tax must be moderated to take account of the under-production associated with the imperfect competition. However, when the planner has two instruments available, the subsidy can be used to fully correct for the under-production and so the pollution tax can be freely set at its Pigouvian level.

9.4.2 Nash equilibrium

Now consider the Nash equilibrium in taxes and subsidies. Each country chooses its tax and subsidy rates, taking as given the other country's policies, and the equilibrium behaviour of firms. To derive the equilibrium policies, I begin by characterizing the industry equilibrium when tax and subsidy rates can differ across countries.

Industry equilibrium

The problem for the representative firm based in country i is the same as the problem in (4) except that τ is replaced by τ_i and s is replaced by s_i. The first-order conditions are given by $\theta=t$ and

$$p + s_i + y_i\, p'/2 = 2t_i \tag{9.16}$$

Multiplying (9.16) by n and setting $ny_i = Y_i$ then yields the aggregate reaction function for firms based in country i:

$$2np + 2ns_i + Y_i\, p' = 4nt_i \tag{9.17}$$

An analogous reaction function can be derived for firms based in the other country. Solving for the equilibrium yields

$$2np + p'X = 2n(t_i + t_{-i}) - n(s_i + s_{-i}) \tag{9.18}$$

where $X=(Y_i + Y_{-i})/2$ is the equilibrium consumption in each country. Substituting (9.18) into (9.17) then yields

$$Y_i = X + 2n(t_i - t_{-i})/p' - n(s_i - s_{-i})/p' \tag{9.19}$$

It will soon be shown that the relationship between market share and the relative policy rates reflected in (9.19) creates a strategic incentive for each country to distort its policies so as to capture rent from the foreign country. But it is first necessary to state some comparative static results. The effects of unilateral policy changes in country i on domestic consumption in both countries can be derived from (9.18):

$$\partial X/\partial t_i = 2n/[(2n+1)p' + Xp''] \tag{9.20}$$
$$\partial X/\partial s_i = -n/[(2n+1)p' + Xp''] \tag{9.21}$$

It follows from the second-order conditions for profit-maximization that $\partial X/\partial t_i < 0$ and $\partial X/\partial s_i > 0$. Furthermore, it is straightforward to show that $\partial Y_i/\partial t_i < 0$ and $\partial Y_i/\partial s_i > 0$, and $\partial Y_{-i}/\partial t_i > 0$ and $\partial Y_{-i}/\partial s_i < 0$.[12]

Nash equilibrium taxes and subsidies

Now consider the game between national governments. Each country chooses its policies to maximize domestic welfare taking as given the equilibrium behaviour of firms and the policies of the other country. Domestic welfare is defined as domestic consumer surplus, plus profits to domestic firms (gross of tax payments and net of subsidy receipts), less domestic environmental damage:

$$W_i = \left[\int_0^X p(\tilde{X})d\tilde{X} - pX\right] + (pY_i - t_iY_i) - e(\alpha Y_{-i}/t_{-i} + Y_i/t_i) \tag{9.22}$$

[12] These comparative static results follow directly from the stability of the equilibrium. See Dixit [7] for further discussion of comparative statics in oligopoly.

Differentiating (9.22) with respect to t_i and s_i, and setting $t_i = t_{-i} = t$, $s_i = s_{-i} = s$ and $Y_i = Y_{-i} = X$, yields the symmetric Nash equilibrium conditions:[13]

$$(p - t)(\partial Y_i/\partial t_i) - X - \alpha e'(\partial Y_{-i}/\partial t_i)/t - e'[t(\partial Y_i/\partial t_i) - Y_i]/t^2 = 0 \qquad (9.23)$$

$$(p - t)(\partial Y_i/\partial s_i) - e'[\alpha(\partial Y_{-i}/\partial s_i) + (\partial Y_i/\partial s_i)]/t = 0 \qquad (9.24)$$

It is straightforward to show, using (9.17), that $(\partial Y_i/\partial s_i) = -(\partial Y_i/\partial t_i)/2$ and $(\partial Y_{-i}/\partial s_i) = -(\partial Y_{-i}/\partial t_i)/2$. Making these substitutions in (9.24) and substituting the resulting expression into (9.23) yields

$$t^2 = e' \qquad (9.25)$$

This condition states that in Nash equilibrium the pollution tax is set equal to marginal domestic damage. Two points are noteworthy about this equilibrium tax-setting rule. First, it is inefficient from a global perspective if pollution is transboundary. Recall from (9.14) that global efficiency requires that the tax be set equal to marginal global damage. For a given level of pollution, the equilibrium tax rate is too low from a global perspective when pollution is transboundary. The second point to note is that this inefficiency has nothing to do with trade per se. It is simply a reflection of the usual transboundary externality that would persist even without trade.

Now consider condition (9.24) for the equilibrium subsidy rate. By adding and subtracting $t(dX/ds)$, and noting that $t = e'/t$, this condition can be usefully rewritten as

$$(p - 2t)(\partial X/\partial s_i) + (p - t)[(\partial Y_i/\partial s_i) - (\partial X/\partial s_i)] - e'[(\partial Y_i/\partial s_i) - (\partial X/\partial s_i) + \alpha(\partial Y_{-i}/\partial s_i)]/t = 0 \qquad (9.26)$$

The three terms in (9.26) correspond to three separate incentives underlying the subsidy choice. Consider each term in turn. The first term represents the gain in social surplus (price less marginal domestic social cost) from a marginal increase in domestic consumption. This term reflects the role of the subsidy in correcting for the

[13] Existence of equilibrium is only assured if the subsidy rate cannot be set arbitrarily large. Political consideration of domestic surplus distribution is likely to provide the necessary constraint on policy.

under-production associated with imperfect competition. This is the same role that the subsidy plays in the global planning problem. It has nothing to do with trade per se. Note also that this first term would vanish under perfect competition, when equilibrium price would be equal to the after-tax marginal cost. There are no non-strategic welfare gains from boosting production in the perfectly competitive case.

The second term in (9.26) reflects the role of the subsidy in affecting the distribution of monopoly rents between the two countries. The subsidy tends to boost net exports (Y_i-X) for the home country and thereby transfer rents from the foreign country. Equivalently, it serves to protect domestic firms from foreign firms that might otherwise capture the rents available in the domestic market. This is a purely strategic use of the production subsidy designed to distort trade flows.[14] It is to this use of production subsidies that trade liberalization negotiations have in principle been directed. The potential welfare gains from eliminating this strategic use of the production subsidy are clear. The attempted distortion of trade flows is purely destructive in equilibrium. Both countries attempt to distort trade flows in their favour but these attempts are mutually offsetting in equilibrium. All that remains in equilibrium is the welfare cost of the distorted production decisions.

The subsidy-induced boost to net exports comes at the cost of higher domestic pollution and this tends to moderate the incentive to capture rents through setting a high subsidy. This moderating effect is reflected in the third term in (9.26). It is clearly reminiscent of the pollution shifting effect identified in section 9.3. It tends to reduce the equilibrium subsidy. The magnitude of this moderating effect depends on the degree to which pollution is transboundary. If pollution is purely local ($\alpha=0$) then domestic pollution rises by the entire amount associated with the increase in net exports. The moderating effect is strongest in this case. However, if pollution is to some extent transboundary then there is an offsetting effect: the subsidy-induced reduction in foreign production causes a reduction in domestic pollution. Domestic damage does not increase commensurately with the increase in domestic production because the transboundary element of the pollution associated with the displaced foreign production is eliminated from the domestic environment. If pollution is perfectly transboundary ($\alpha=1$) then the substitution of domestic production for foreign production has no impact at all on the domestic environment. Domestic pollution rises only by the amount due to the subsidy-induced increase in foreign consumption.[15] The incentive to set a lower subsidy is weakest in this case.

[14] The production subsidy plays the same strategic role as of an export subsidy. In fact, in this symmetric setting the two are substitute instruments.

[15] To see this in (9.26), note that $Y_i+Y_{-i}=2X$, so $(\partial Y_i/\partial s_i) + \alpha(\partial Y_{-i}/\partial s_i) = 2(\partial X/\partial s_i)$ when $\alpha=1$.

If pollution is purely local then the conflicting incentives associated with rent capture and pollution shifting are exactly offsetting. To see this, rewrite (9.26) as

$$(p - 2t)(\partial Y_i/\partial s_i) - e'\alpha(\partial Y_{-i}/\partial s_i)/t = 0 \qquad (9.27)$$

When $\alpha=0$ the only incentive remaining is to correct for the under-production: the subsidy is chosen to equate price with marginal domestic social cost. The strategic incentive to distort the subsidy is neutralized for the following reason. When pollution is purely local the entire increase in net exports contributes to new domestic pollution with no transboundary offset. These net exports therefore have a domestic environmental cost of $e'/t=t$. But this is precisely the amount of marginal rent captured on net exports when price is set at marginal domestic social cost. There is therefore no net gain to boosting net exports by setting a higher subsidy than is needed to correct for the under-production problem. In contrast, when pollution is at least partly transboundary ($\alpha>0$) then boosting net exports can capture rents in excess of the domestic environmental cost incurred because the substitution of domestic production for foreign production does not have a commensurate effect on domestic damage. In this case the equilibrium subsidy is set too high relative to what is globally efficient and gives rise to an equilibrium price below marginal domestic social cost.

This is clear from (9.27) since $(\partial Y_{-i}/\partial s_i)<0$. This distortion imposes a welfare cost on both countries. When pollution is transboundary there are two additional sources of inefficiency in equilibrium. The first is that associated with the equilibrium tax-setting rule discussed earlier. The equilibrium tax is set equal to marginal domestic damage rather than marginal global damage. The second source of inefficiency relates to the role of the subsidy in correcting for under-production. Recall from (9.15) that global efficiency requires price to be equated with marginal global social cost. However, in the non-cooperative equilibrium, each country is concerned only with marginal domestic social cost; this excludes the cost of production associated with damage done outside its boundaries. Thus, strategic trade considerations aside, each country will tend to over-subsidize production in correcting for the perceived under-production associated with imperfect competition. It is important to reiterate that neither of these inefficiencies are due to strategic distortions associated with trade. They are due to the usual transboundary externality problem and would persist in a non-cooperative equilibrium between closed countries when pollution is transboundary.

When pollution is purely local there are no transboundary externalities and there are no strategic trade distortions. In this case the Nash equilibrium is efficient. Note that this equilibrium coincides with the equilibrium in section 9.3 without subsidies

when there is perfect competition and no transboundary pollution. The reason is straightforward: the equilibrium subsidy effectively implements a competitive industry equilibrium allocation.

9.5. EQUILIBRIUM WITH RESTRICTED SUBSIDIES

I now turn to the Nash equilibrium when subsidies are restricted by a trade liberalization agreement. I confine consideration to an agreement which prohibits the use of subsidies for trade-related goals. In particular, the agreement allows the use of subsidies to correct for the under-production associated with imperfect competition but prohibits the use of subsidies for the purely strategic goal of distorting trade flows. I assume that the permitted subsidy is that which equates equilibrium price with marginal global social cost. That is, the trade agreement explicitly recognizes the domestic and transboundary costs of pollution. We have seen from the previous section that there is no equilibrium incentive for either country to set a subsidy lower than that which equates price and marginal global social cost, so the agreed restriction on subsidies will be binding in equilibrium.[16] It follows that in the post-agreement equilibrium:

$$p = t + (1+\alpha)e'/t \tag{9.28}$$

What does the agreement imply for equilibrium pollution taxes? Expression (9.23) specifies the Nash equilibrium tax rate choice for a given subsidy level. Substituting (9.28) into (9.23) therefore yields an expression for the Nash equilibrium tax rate when the subsidy is set at the restricted level:

$$(1 - e'/t^2) = \alpha e'[(\partial Y_i/\partial t_i) - (\partial Y_{-i}/\partial t_i)]/tX \tag{9.29}$$

It is clear from (9.29) that if there is no transboundary pollution ($\alpha=0$) then the equilibrium tax is set equal to marginal domestic (and global) damage. That is, the agreement does not distort the tax-setting rule relative to the pre-agreement equilibrium, and moreover, the post-agreement equilibrium is globally efficient. This follows from the fact that there is no strategic distortion of trade flows in the pre-agreement equilibrium when pollution is not transboundary. The agreement simply binds countries to behave in a manner that is privately optimal anyway.

[16] In the case of no transboundary pollution it will weakly binding.

On the other hand, if pollution is at least partly transboundary then the agreement causes a negative distortion of the tax setting-rule relative to the pre-agreement equilibrium. When $\alpha>0$ the RHS of (9.29) is negative, and so $t^2<e'$. That is, the pollution tax is set below marginal domestic damage in the post-agreement equilibrium. This is clearly inefficient: efficiency requires that the tax be set equal to global marginal damage. This inefficiency reflects both the usual transboundary externality, and the strategic distortion of the pollution tax in response to the trade agreement. This strategic distortion arises because the agreement does not eliminate the incentive for each country to influence trade flows; it simply restricts the instruments that can be used for that purpose. When the subsidy is restricted by agreement, the pollution tax must play the role of both a corrective tax and a strategic trade instrument.

It is not possible to make a definitive welfare comparison between the pre- and post-agreement equilibria when there is transboundary pollution because both equilibria are inefficient. However, the welfare cost associated with the distortion of the pollution tax has the potential to more than offset the welfare gains associated with restricting subsidies. Both countries could be made worse-off by the trade liberalization agreement. To highlight the potential gains and losses, it is perhaps useful to summarize the nature of the distortions in each equilibrium relative to the globally efficient solution when pollution is transboundary. In the pre-agreement equilibrium there is a strategic incentive to set too high a subsidy from a global perspective. This is compounded by the transboundary externality which inflates the non-strategic element of the subsidy (that part directed at the under-production problem). There is therefore too much production. Moreover, the pre-agreement equilibrium tax-setting rule ignores the damage done by transboundary pollution and so is negatively distorted. However, the actual equilibrium tax rate could be higher or lower than in the efficient solution because marginal domestic damage (to which the tax rate is equated) will be higher due to the higher level of production if damage is strictly convex. In contrast, the post-agreement equilibrium is characterized by the efficient subsidy-setting rule but a tax-setting rule that is negatively distorted by both strategic trade incentives and the transboundary externality. The actual post-agreement equilibrium tax rate is too low, and the induced technology is too dirty. This in turn generates more production than is efficient.

9.6 CONCLUSION

This chapter has examined the strategic incentives to distort pollution taxes in open economies with imperfect competition. I began by examining a world economy in

which a pollution tax is the only instrument. The associated free-trading equilibrium exhibits pollution taxes that are distorted away from the globally efficient taxes by three separate effects: the usual transboundary externality effect, a rent capture effect and a pollution-shifting effect. The rent capture effect tends to reduce equilibrium taxes as each country attempts to gain a competitive advantage over its trading partner and thereby capture foreign rent through net exports. The pollution-shifting effect tends to raise equilibrium taxes as each country attempts to transfer production and its associated pollution to the other country. This effect vanishes if pollution is perfectly transboundary because shifted pollution causes as much damage to the domestic environment as does domestic pollution. The net effect on symmetric equilibrium taxes is negative, except in the special case of perfect competition with no transboundary pollution. In this case the two effects are mutually offsetting and the Nash equilibrium is efficient.

I then turned to a setting in which both a pollution tax and a production subsidy are available to national governments. My results indicate that the properties of the non-cooperative and restricted equilibria in this setting depend crucially on the degree to which pollution is transboundary. The equilibrium in which taxes and subsidies are set non-cooperatively is globally efficient in the absence of transboundary pollution. In particular, there is no distortion of either pollution taxes or production subsidies relative to the globally efficient solution. Conversely, when pollution is at least partly transboundary then the non-cooperative equilibrium is inefficient. The equilibrium subsidy is positively distorted by the strategic incentive to capture foreign rents (or equivalently, to protect domestic rents). The equilibrium tax-setting rule is negatively distorted, reflecting the usual transboundary externality. There is no purely strategic distortion of the pollution tax; the entire strategic trade role falls on the subsidy. I then examined a restricted equilibrium in which countries agree to prohibit the use of subsidies for trade-related goals. The use of a production subsidy is restricted to correcting for the under-production associated with imperfect competition. In the absence of transboundary pollution, this agreement changes nothing. The pre- and post agreement equilibria coincide exactly and both are efficient. In contrast, when pollution is transboundary, the strategic trade role that before the agreement lay with the subsidy is taken on by the pollution tax in the post-agreement equilibrium. In particular, the tax-setting rule is negatively distorted relative to the pre-agreement equilibrium and relative to the globally efficient solution. The agreement therefore has an ambiguous effect on welfare when pollution is transboundary. Both countries could be made worse off by the agreement. Only when there is no transboundary pollution is the welfare effect of the agreement unambiguous. In that case it is welfare neutral.

The pollution tax distortion and the ambiguous welfare effect associated with the trade liberalization agreement are of course due to the less-than-comprehensive

nature of the agreement. A comprehensive coordination agreement between symmetric countries covering all policy variables cannot make either country worse off. However, to be assured of welfare gains, the agreement must be truly comprehensive. All policy instruments may need to be coordinated. Any policy instruments that are not explicitly coordinated potentially become subject to strategic distortions when the strategic use of other instruments is restricted. The key point is that the incentives to distort trade flows are not eliminated by a trade liberalization agreement. A trade agreement only restricts the means by which countries can act on those incentives. International agreements must extend beyond the elimination of traditional trade barriers such as tariffs and "unfair" subsides if they are to reliably deliver the welfare gains promised by textbook models of competitive world trade.

REFERENCES

Barnett, A. (1980) The Pigouvian tax rule under monopoly. *American Economic Review*, 70, 1037-1041.

Barrett, S. (1994) Strategic environmental policy and international trade. forthcoming in *Journal of Public Economics*.

Cumberland, H. (1979) *Interregional pollution spillovers and consistency of environmental policy* in H. Siebert et. al. (eds), *Regional Environmental Policy: the Economic Issues*. New York: New York University Press.

Dixit, A. (1986) Comparative statics for oligopoly. *International Economic Review*, 27, 107-122, (1986).

Kennedy, P. (1994), Equilibrium pollution taxes in open economies with imperfect competition, forthcoming in *Journal of Environmental Economics and Management*.

Lee, D. (1975) Efficiency of pollution taxation and market structure. *Journal of Environmental Economics and Management*, 22, 69-72.

Markusen, J., E. Morey and N. Olewiler (1992) *Non-cooperative equilibria in regional environmental policies when plant locations are endogenous*. mimeo, University of British Columbia.

Mintz J. and H. Tulkens (1986) Commodity tax competition between member states of a federation: equilibrium and efficiency. *Journal of Public Economics*, 29, 133-172.

Oates W. and R. Schwab (1988) Economic competition among jurisdictions; efficiency enhancing or distortion inducing?. *Journal of Public Economics*, 35, 333-354.

Ulph, A. (1992) *The choice of environmental policy instruments and strategic international trade*. in Pethig, R. (ed.), Conflicts and Cooperation in Managing Environmental Resources, Berlin: Springer Verlag.

Wildason, D. (1988) Nash equilibria in models of fiscal competition. *Journal of Public Economics*, 35, 229-240.