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Environmental Regulation and the Location of Polluting Industries

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Abstract

Does international tax competition in the environmental field lead to undesirably low levels of environmental regulation and to unacceptable disruptions of environmental quality? The paper tries to answer this question in a noncompetitive partial-equilibrium framework. There is one firm that wishes to establish a plant in one of n countries. The paper shows that tax competition may lead to emission taxes that are either too low or too high. They may be so high that the investment is not undertaken, although this would be optimal if the countries cooperated. On the other end of the spectrum, a scenario in which taxes are driven to zero becomes possible if there are substantial transfrontier pollution effects.

Key words: environmental policy, international capital movements, imperfect competition, tax competition

1. Introduction

Do changes in environmental regulation lead to the delocation of polluting industries? If they do, does this create incentives for the policy maker to adjust environmental taxes and standards in such a way that delocation is avoided? These are two of the central questions in the current debate on environmental policies in open economies. Business people often argue that tough environmental standards negatively affect the competitiveness of domestic firms or of the economy as a whole (whatever that may mean). In the long run, firms will move to countries with less restrictive environmental policies. Environmentalists fear that policy makers listen too much to these arguments and that they are forced to implement lax environmental standards for reasons of international competitiveness. Ultimately, so the argument goes, this may lead to a kind of a rat race where each country tends to undercut the environmental taxes prevailing elsewhere, and this may have disastrous consequences for environmental quality.

The first question as to whether environmental regulation has an impact on industry location is an empirical one. Several studies have addressed this issue, and the results are ambiguous. Walter (1982) evaluates data on the sectoral and firm levels and comes to the conclusion that generally there is no evidence that pollution-intensive industries have moved to less regulated countries or regions. Delocation has taken place only in special cases, when major projects have been obstructed for environmental reasons. Similar results are obtained by Bartik (1988) and Leonard (1988). Rowland and Feiock (1991), in contrast, come to the conclusion that environmental regulation does affect locational decisions of investors in the U.S. chemical industry. The relationship found by Rowland and Feiock (1991) is highly nonlinear: there is a threshold value of pollution-abatement costs below which dislocation effects of environmental-policy changes cannot be observed. Hettige, Lucas, and Wheeler (1992) and Lucas, Wheeler, and Hettige (1992) report that there has been a relocation of environmentally intensive industries to developing countries. They infer this from the fact that low-income countries have experienced higher growth rates of pollution intensity per unit of output than high-income countries during the 1970s and 1980s when industrialized countries tightened their environmental standards. Similar results are reported by Low and Yeats (1992). To summarize, there is some evidence that environmental regulation affects locational decisions, but much less than one would expect given the excitement with which this issue is discussed in the public. Future research into this problem area is desirable.

The second question whether the threat of delocation may lead to a disastrous competition among jurisdictions in the field of environmental regulation is the subject of this paper. Only a small number of papers have dealt with this question up to now. This literature may be divided into two branches.

On the one hand, there are competitive models that look at the economy as an aggregate. This literature encompasses many international tax competition models, and it is based on the traditional approach to international factor movements developed by Jasay (1960), MacDougall (1960), and Kemp (1964). Tax competition models have been used to analyze interjurisdictional competition with various policy instruments like capital-income taxes (Zodrow and Mieszkowski, 1986; Wilson, 1987, Wildasin, 1988) and commodity taxes (Mintz and Tulkens, 1986). Environmental legislation as the instrument of inter-jurisdictional competition has been addressed by Oates and Schwab (1988), Long and Siebert (1991), and Rauscher (1994). It is shown there that in a first-best world with many small countries welfare-maximizing policy makers have no interest in undercutting foreign environmental taxes. Oates and Schwab (1988) have looked also at second-best situations. If environmental taxes are used to correct for distortions generated by other taxes, tax competition may result in undesirably low emission taxes. Long and Siebert (1991) and Rauscher (1994) have considered the large-country case where environmental legislation can be used to influence the remuneration of mobile factors of production. In this case, the environmental policies are not Pareto optimal, too. The capital-rich country, striving for a high interest rate, prefers a lax environmental policy, wheras the capital-poor country chooses a tough policy since this tends to reduce the world market rate of interest.

On the other hand, there are partial-equilibrium models of noncompetitive markets. Models where one country takes foreign environmental policies as given and chooses its own welfare-maximizing policy have been investigated by Markusen, Morey, and Olewiler (1993) and Motta and Thisse (1994). They generalize the Brander and Krugman (1983) model of reciprocal dumping by making the number of firms and plants endogenous. The number of firms that are active on the supply side on the market depends inter alia on the environmental regulation. Changes in emission taxes or standards may induce firms to close down plants or open new ones. With these changes in market structure, it is not surprising that even marginal changes in environmental regulation may have large effects on environmental quality and welfare. The model has been extended to a Nash equilibrium framework by Markusen, Morey, and Olewiler (1995) and Ulph (1994). Here the interactions of both governments are considered.[1] It is shown that not only the rat race leading to low environmental standards in both countries is possible but also a scenario for which Markusen, Morey, and Olewiler (1995) have coined the expression "not in my back yard." In this case, the number of polluting firms is smaller than the optimal one.

The present paper falls into the second category, that of noncompetitive partial-equilibrium models. It uses a variant of the Markusen, Morey, and Olewiler (1995) model, which is simplified in some respects and more complicated in some others. Markusen, Morey, and Olewiler consider a situation where there is one polluting firm that decides on the location of its plants. Entry by additional firms is excluded by high set-up costs. There are two kinds of fixed costs, that of being in the market and that of setting up a plant. The variable costs include pollution abatement and trade costs. The firm may build a plant in the home country, in the foreign country, in both of them, or in neither of them, and the decision is influenced by the environmental policies in the two countries. Unfortunately, this model turns out to be rather complex even in the case of only one firm. Markusen, Morey, and Olewiler, therefore, use a numerical example to derive some results. The present model tries to avoid this complexity by neglecting trade costs. Thus, a scenario in which the firm opens up more than one plant is not possible: a single plant suffices to serve the whole market. The model then turns out to be solvable rather easily, and the results can be interpreted neatly. The additional features of the model are the larger number of countries and the consideration of transfrontier pollution problems. A similar approach has been chosen by Hoel (1994).

The paper is organized as follows. The next section presents the model. Section 3 characterizes the cooperative solution. Section 4 deals with jurisdictional competition in a world in which all countries are equal and where there is no transfrontier pollution. Section 5 introduces diversity and transboundary pollution spillovers. In Section 6, the impact of additional policy instruments such as subsidies will be discussed. The final section summarizes the results.

2. The model

Consider a market for a good whose production is subject to increasing returns to scale and substantial environmental externalities. Increasing returns tend to lead to noncompetitive market structures, and in this model there will be a natural monopoly: a single firm serves the whole market for final goods. In the factor market, the firm is a price taker since it competes with firms that are active in other sectors of the economy. The production requires an environmental resource as an input. This input is used up during the production process, and this contributes to environmental deterioration. The jurisdiction that hosts the polluting plant wishes to avoid unnecessary depletion of environmental resources and therefore regulates the producer by imposing a tax on the use of environmental resources. This will be referred to as the *emission tax* during the rest of the paper. The jurisdiction that hosts the producer is not the only one; there are other jurisdictions that are potential locations of the polluting plant. Thus, there are $n + 1$ relevant actors in the model—one firm and n jurisdictions. The jurisdictions will be called *countries* for the sake of convenience. It should, however, be noted that this term encompasses all kinds of jurisdictions down to the community level that enjoy some discretion and sovereignty in their environmental policies.

The model structure is the following one. The producer is a monopolist vis-à-vis the consumers. She decides whether to build a plant or not, where to build it, and how much to produce. She takes as given the environmental regulation. The government of the hosting country is a Stackelberg leader vis-à-vis the monopolist. If governments do not cooperate, they play Nash against each other, and each country takes the environmental tax rates in the rest of the world as given. The game is solved in the usual backward fashion.

2.1. The firm

Due to large fixed costs, there will never be more than one supplier in the market. If these fixed costs are interpreted as being set-up costs of a plant and if transport and other trade costs are sufficiently small, there will be only one plant from which the whole market is served. Fixed costs being deduced, the production is characterized by constant returns to scale. This implies that the variable costs are $c(w, t)q$, q is the output, t is the environmental tax rate, w is a vector of remunerations of the private factors of production, and $c(.,.)$ is the unit-cost function. $c(.,.)$ is increasing in its arguments, concave, and homogeneous of degree one. The utilization of environmental resources, which is proportional to emissions, e, is determined by Shephard's lemma. Choosing the units of measurement appropriately, emissions can be written as

$$e = c_t(w, t)q, \tag{1}$$

where the subscript represents the partial derivative of a function with respect to the variable in question. Let the countries be identical with respect to demand, and let the inverse demand function in each country be $p(q/n)$. Then, the profits turn out to be

$$\Pi = p(q/n)q - c(w, t)q - f, \tag{2}$$

where f denotes the set-up costs the firm has to bear if it raises a plant. The first-order condition for profit maximization is

$$p(q/n) + \frac{p'(q/n)q}{n} = c(w, t), \tag{3}$$

and this condition is sufficient if the revenue function is strictly concave. We assume that this is the case. The profit-maximizing output, q, depends on the emission tax rate, t. Let this be denoted by a function $\omega(t)$. Its slope is

$$\omega' = \frac{dq}{dt} = \frac{c_t}{\frac{2p'}{n} + \frac{p''q}{n^2}} < 0, \tag{4}$$

where the arguments of the functions have been dropped for convenience. In the case of a linear demand function, this can be simplified

$$\omega' = \frac{nc_t}{2p'}. \tag{4'}$$

The graphical representation is straightforward. Figure 1 depicts the aggregate demand curve, $q(p)$, the marginal-revenue curve, mr, the marginal cost line, $c(w, t)$, and the average cost curve, ac. The initial scenario depicts a situation where the price is larger than the average cost—that is, where the firm makes a profit. If the emission tax is raised, the cost curves will be shifted upward, the supply will be reduced, and finally profits may turn out to be negative. The plant will not be built. This situation is depicted by dashed lines in the diagram.

The critical tax level, t^c, at which the firm decides not to build the plant can be determined by setting $\Pi = 0$ in equation (2), using the first-order condition (3) and noting that the optimal supply is a function of the tax rate:

$$\frac{p'(\omega(t^c))\omega(t^c)}{n} = \frac{f}{\omega(t^c)}. \tag{5}$$

This formula states that the markup over marginal costs must equal the average fixed cost. Total differentiation yields the expected result that t^c is a declining function of f. The higher the fixed cost the smaller the tax rate necessary to make the firm leave the market.

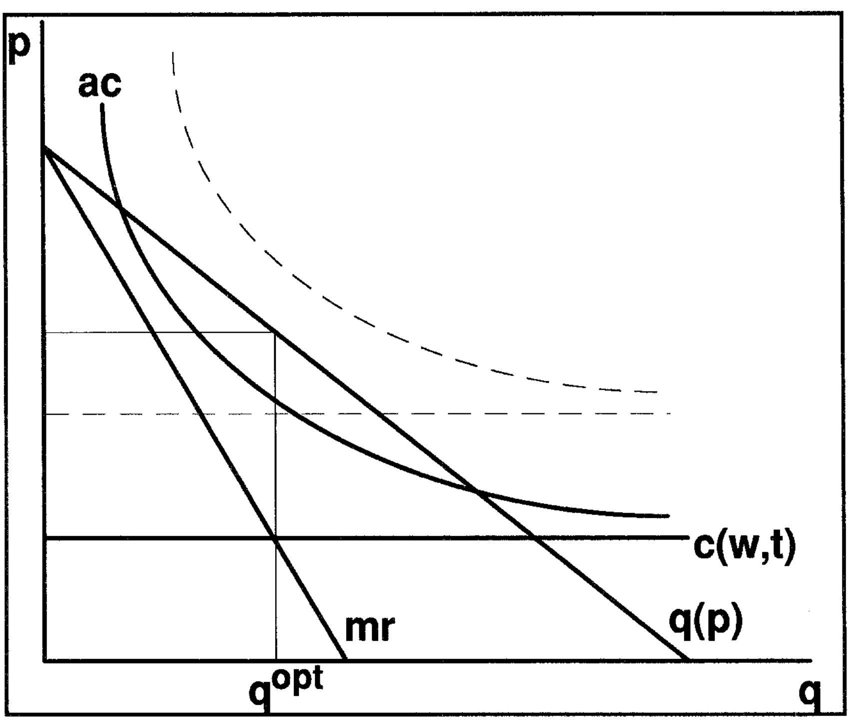

Figure 1. Behavior of the monopolist.

2.2. *The* n *countries*

As far as demand is concerned, the n countries are identical. However, they may be different with respect to the effects of pollution. These differences may be due to asymmetries in the transfrontier pollution process, to differences in assimilation capacities, and to differences in preferences, such as in environmental concern. All these aspects are captured in a single parameter, a^{ij} $(i, j = 1, \ldots, n)$. This parameter denotes the effect of one unit of emissions in country i on the environment in country j. The environmental disruption is evaluated by an increasing and convex damage function $d(.)$.

There is one major difference between the host country and the rest of the world: it can appropriate the tax revenue. The other positive welfare component, which is equal for all countries, however, is the utility derived from consumption—that is, the consumer surplus. The welfare of the host country turns out to be

$$w^i = -d(a^{ii}c_tq) + tc_tq + \int_0^{q/n} p(\varphi) - p(q/n)d\varphi, \tag{6}$$

where q now (and for the rest of the paper) denotes the profit-maximizing output of the monopolist. For the rest of the world, one obtains

$$w^j = -d(a^{ij}c_tq) + \int_0^{q/n} p(\varphi) - p(q/n)d\varphi \qquad i \neq j. \tag{7}$$

3. Coordinated environmental policies

If the countries coordinate their environmental policies, they maximize the total welfare—that is, the sum of all w^i $(i = 1, \ldots, n)$. Side payments may be required to compensate potential losers from an international environmental agreement, but they need not be considered in the model since they are lump-sum transfers that do not affect the allocation. It is assumed that the properties of the welfare function are such that someone will host the firm; the boundary solution, $q = 0$, will not be considered in much detail. The first-order condition for an optimum is

$$t^i = \sum_{j=1}^{n} a^{ij}d' + \frac{\frac{1}{n}p'q\omega' - c_tq}{c_{tt}q + c_t\omega'}, \tag{8}$$

where country i is the host country. The first term on the right side is the marginal environmental damage. The other term corrects for the distortion, which is due to the noncompetitive market structure. It is negative since its numerator is positive and the denominator is negative. A monopolist produces less than socially optimal, and this can be taken into account by subsidization of output. Here the subsidy takes the shape of a low emission-tax rate.[2] It should be noted that policy determined by equation (8) is not the first-best policy. Since there are two distortions in the model (an environmental externality and the noncompetitive market structure), the first-best policy would require additional policy instruments. If the policy makers were able to restrict monopoly power by setting a maximum price, then the optimal emission tax rate would equal the marginal environmental damage—that is, the second term on the right side of equation (8) would vanish.

Since there are n potential host countries, there may be up to n different solutions to equation (8) and it depends on the values of a^{ij} which location is the optimal one. Some special cases may be considered:

- No transfrontier pollution ($a^{ij} = 0$ for $i \neq j$). The country with the lowest a^{ii} should host the polluter.
- Equal impacts on all countries ($a^{ij} = a^{kl}$ for all $i, j, k, l = 1, \ldots, n$). This is the case of a global environmental problem where the damage is independent of where the pollutant is discharged. All potential locations are equally optimal.
- Linear damage function ($d' = 0$). The country i for which $\Sigma_{j=1}^{n} a^{ij}$ is minimized should host the firm.

For the general case where the damage function is nonlinear and the a^{ij} differ across countries, an explicit solution of the optimization problem is impossible.

Figure 2 illustrates the case without transboundary pollution. Four curves are depicted:

- Environmental damage, d is a declining function of the tax rate. The second derivative with respect to t is

$$(c_{ttt}q + 2c_{tt}\omega' + c_t\omega'') \sum_{j=1}^{n} a^{ij} d' + (c_{tt}q + c_t\omega') \sum_{j=1}^{n} (a^{ij})^2 d'',$$

  and its sign is indeterminate in the general case. If, however, the production function is Cobb-Douglas and the demand function is linear, then $c_{ttt} > 0$ and $\omega'' = nc_{tt}/(2p')$ > 0. These are sufficient conditions for the environmental damage being a convex function of the tax rate.
- The tax revenue, tr, is an increasing function of the tax rate if the tax rate is small and may have a negative slope for a large tax rate. This is the Laffer-curve property. The second derivative is

$$2(c_{tt}q + c_t\omega') + (c_{tt}q + 2c_{tt}\omega' + c_t\omega'')t.$$

  This curve is concave for small values of t and may be convex for larger values.
- Consumer surplus, cs, is a declining function of the tax rate. In the case of a linear demand function, the marginal consumer surplus turns out to be $e/2$. Thus, the cs curve is concave in this case.
- The fourth curve is obtained by the addition of tax revenue and consumer surplus.

The optimum tax rate, t^*, is located where the d curve and the $(tr + cs)$ curve have the same slopes. Figure 2 depicts an interior optimum—that is, $t^* < t^c$.

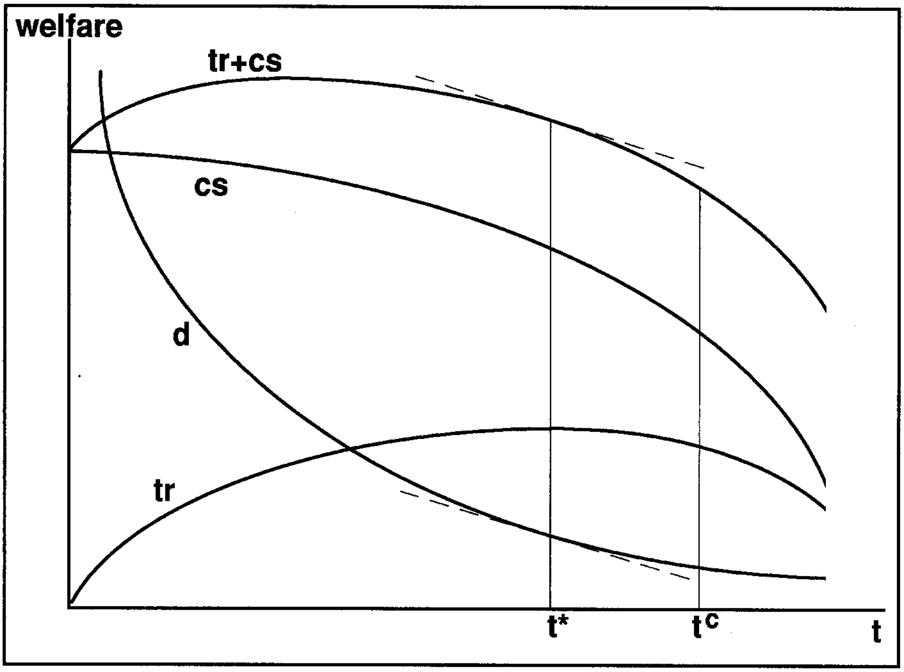

Figure 2. Optimal environmental policy.

4. Noncooperative environmental policies

Now consider a situation in which the n countries compete for the foreign investor. For the sake of simplicity, we start with a situation in which all countries are equal and there is no transboundary pollution. The country that hosts the foreign investor imposes two externalities on the rest of the world. First, the goods that are produced in the polluting plant are available abroad, and this generates consumer surpluses in the other countries. Second, the host country appropriates the whole tax revenue, which is then not available for other countries. The cost of being the host is the domestic environmental damage.

Figure 3 depicts the situation from the point of view of a single country for different types of the environmental-damage function. d^1 represents a situation in which environmental damages are rather small and d^2, d^3, and d^4 depict damage functions with higher levels of environmental damage for given emission taxes. Since the damage function is simply shifted upward, the optimal tax rate, t^*, is not affected. $(tr + cs)^i$ represents tax revenue plus consumer surplus from the point of view of a single country. This function lies below the $(tr + cs)$ line of the cooperative case since a single country receives only one nth of the total consumer surplus. We use Figure 3 to derive the results of the environmental tax competition.[3]

Consider first a scenario in which each country (correctly) conjectures that there will be someone who is willing to host the polluter. In this case, the consumer surplus accrues

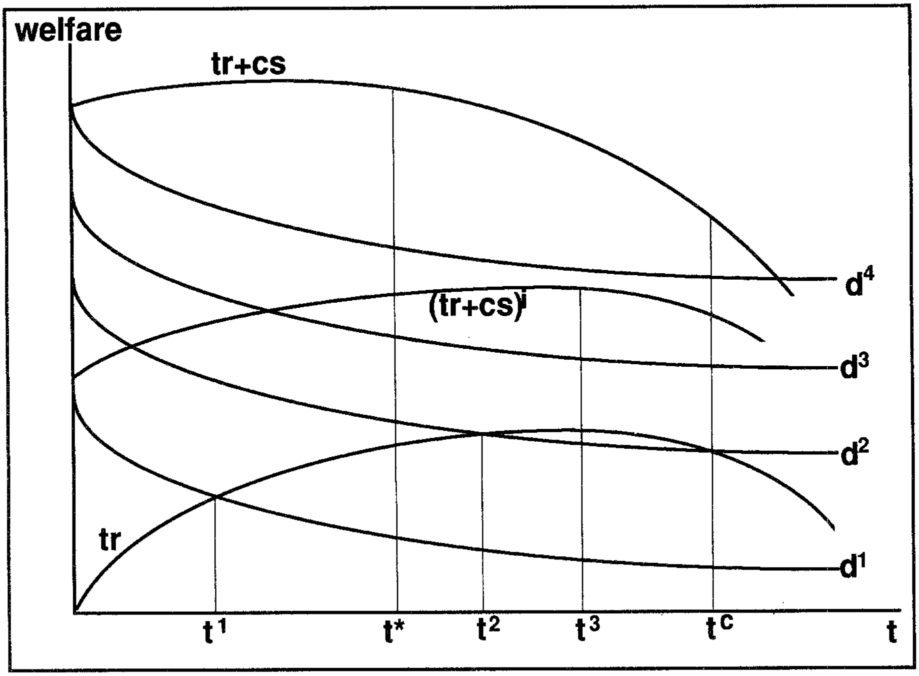

Figure 3. Jurisdictional competition.

to any country independently of whether it decides to be the host itself or not. Thus, the decisive variables are the tax revenue and the environmental damage. Assume that the environmental damage is small (d^1). Over a wide range of tax levels, the tax revenue exceeds the environmental damage. In this situation, each country is better off it itself hosts the polluter than if the plant is located abroad. Since the firm moves to the country with the lowest tax level, each country has an incentive to undercut foreign emission taxes. This incentive vanishes when tax revenue equals environmental damage—that is, at a tax level of t^1. This is the case of a rat race. Jurisdictional competition results in underregulation and too much pollution.

In case 2, the environmental damage is larger (d^2). The range of positive net welfare effects for the host country is reduced. At the optimal tax level, t^*, the environmental damage exceeds the tax revenue and none of the countries takes the burden of hosting the polluting plant. The jurisdictional competition results in a tax level t^2, which is too high. The host country allows the monopolist to pollute its backyard but only a little bit.

If the environmental damage is even larger (d^3), it exceeds the tax revenue for all tax rates below t^c. However, the total benefit, $(tr + cs)^i$, is larger than the cost of environmental disruption. Thus, even the host country would benefit if the investment were undertaken, but it prefers the plant to be established elsewhere. This is a chicken-game situation.[4] The host country is the chicken. This game has n pure-strategy equilibria, and it is not clear whether one of them will be attained. See Fudenberg and Tirole (1991, pp. 18–19). If mixed strategies are used, a scenario becomes feasible in which the plant is not built although everyone would benefit from it. If the plant is built, the tax rate t^3 will be offered by the chicken. This is the tax rate at which the country maximizes its national welfare—that is, $(tr + cs)^i - d$. It is too high.[5] It should be noted that the relationship between environmental damage and the emission tax is nonmonotonous. A reswitching phenomenon turns up as we move from scenario 2 to scenario 3.

Finally, if the environmental damage is very large (d^4), none of the countries benefits from being the host. The investment will not be undertaken because of the traditional prisoner's dilemma problem. It would be individually irrational to provide the consumer surplus to the citizens of other countries if this results in an individual welfare loss. This corresponds to the "not in my backyard" scenario of the Markusen, Morey, and Olewiler (1992) paper.

Two external effects generate the deviation from the desirable environmental policy. On the one hand, the tax revenue generates a kind of common-pool problem. The country that appropriates the revenue by becoming the host makes it unavailable for the other countries. If the tax revenue is large compared to the environmental damage, the jurisdictional competition will induce the governments to undercut foreign emission tax rates. On the other hand, there is the consumer surplus of which the home country can appropriate only one nth. Thus, by being the host a country generates positive externalities because it makes the good available to foreign consumers. In a noncooperative situation, there are no incentives to produce positive externalities, and this explains the not-in-my-backyard result when the cost of being the host is large.

Finally, one may wish to consider a scenario where it is not optimal from a global point of view that the investment be undertaken. If the global welfare effect of the investment is negative, then the welfare loss for any potential host country is even greater. There are no incentives to become the host. An investment that is undesirable will never be made. This result may, however, be changed if transfrontier pollution is introduced.

5. Differences between countries and transfrontier pollution

The preceding analysis was based on a simplified version of the model in which all countries are equal and there are no transfrontier pollution spillovers. These assumptions will be abolished now. In a first step, the case of differences between countries will be considered. We will then turn to the issue of transfrontier pollution.

If countries are different—that is, if $a^{ii} \neq a^{ij}$ for $i \neq j$—then the country with the lowest a^{ii} will be able to undercut the other competitors and will host the polluting plant—provided that the net benefit (tax revenue minus damage) is nonnegative. This is efficient since the polluting plant should be located where the environmental cost is minimized. But this country will in general not choose the optimal tax rate, t^*. It is easy to show that in a world with different countries it is less likely that the optimum tax rate, t^*, is undercut than in a homogeneous world. This can be seen from Figure 3. Let us assume that the damage function depicted in this figure is that of the country with the lowest a^{ii}. The jurisdictional competition will be stopped when the country with the second lowest level of a^{ii} reaches the break-even point where tax revenue equals environmental damage. The remaining country may have an incentive to reduce the tax rate even more if this is welfare improving. However, it is unlikely that it reduces the tax rate towards the level at which the net benefit vanishes.[6] Thus, the tax rates offered by the country are larger than t^1 and t^2, respectively. There will be a tendency toward larger tax rates. Of course, the cases of the chicken game and the prisoner's dilemma are also feasible.

Next consider the case of global pollution, where the damage to the environment is independent of the source of the emission. Examples are ozone depletion due to CFC emissions or the greenhouse effect. In this case, all a^{ij} are equal. The game can be solved in two steps. First, one may ask whether there will be a country that offers to be the host. This will happen if the sum of tax revenue and consumer surplus exceeds the environmental damage to a single country. This may be the case even in a situation in which it is not desirable from a cooperative point of view that the investment be undertaken.[7] The jurisdictional competition now takes the following shape. The opportunity cost of undercutting foreign tax rates becomes infinitesimally small. Like the consumer surpluses that accrue to all countries independently of who is the host, environmental disruption is now independent of the locational decision of the monopolist as well. Thus, from the point of view of an individual government, a discrete change in tax revenue has to be compared to marginal changes in consumer surplus and environmental disruption. In order to appropriate the tax revenue, the countries will undercut each other's emission tax rates until the tax revenue becomes marginal. There will be a tax competition toward a zero tax rate.

Finally, let us consider the general case where there is transboundary pollution and the countries are different. In order to exclude a tax competition toward zero regulation, it is assumed that each country is the main source of its own pollution—that is, the diagonal elements of the transfrontier-pollution matrix dominate the other elements in each column ($a^{jj} > a^{ij}$ for all $i, j, i \neq j$). If the environmental damage is a linear function of emissions, then it is best to locate the polluter in country i, for which the sum of all a^{ij} ($j = 1, \ldots, n$) is minimized. This is, however, not necessarily the country that will win the jurisdictional competition. And even if it were, the emission level would presumably be too high. Assume that there is a country that has an incentive to make the first move and host the polluter. Then the tax competition is driven by the following rationale. The benefit of being the host is the tax revenue. The opportunity cost is the domestic environmental damage minus the damage that would occur via transborder spillovers if the plant would be set up abroad. One country after the other drops out of this tax game until the two countries with the lowest opportunity costs remain in the game. This pair of countries is characterized by

$$\min_{i,j}(\max(a^{ii} - a^{ji}, a^{jj} - a^{ij})). \tag{9}$$

Of these two countries, the country with the lower value of $a^{jj} - a^{ij}$ becomes the host country, and the larger value of $a^{jj} - a^{ij}$ determines the tax rate that is finally charged per unit of emissions from the investor. Like in the case of no transfrontier pollution and different countries, two additional scenarios are possible. There may be an interior optimum if the country that is finally established as the host country can increase its welfare by further tax reductions. Moreover, it is possible that no one wants to have the polluter in her or his back yard if the self-pollution effects are substantial.

As an example consider the problem of North Sea pollution. Due to the predominant direction of currents, the transfrontier pollution matrix tends to be approximately triangular. It would be efficient to locate polluting firms on the Eastern shore—for instance, in Denmark. However, Great Britain has the lowest self-pollution coefficients and therefore has the best position in the jurisdictional competition—at least at a first glance. One may argue that the enterprise will be located in the wrong country and the level of regulation will be too low. However, if Denmark is threatened by pollution from the United Kingdom, its opportunity cost of hosting the polluter shrinks. Denmark may therefore be ready to undercut the low British tax rates in order to reap the net benefit from hosting the plant.

6. Additional policy instruments

Up to now, we have dealt with a single policy instrument (or emission tax) in a situation where multiple externalities are present. This is not a first-best policy. Therefore, let us introduce a lump-sum subsidy, s, as an additional policy variable. Initially, a situation without transfrontier pollution is considered. Assume that environmental damages are small and all countries are interested in becoming the host. A country that wants to be more attractive to the foreign investor than its competitor has to offer her a higher level of profits. This has to be done such that the country's resources are used in the most efficient way. The optimization problem is to maximize the net benefit (tax revenue minus subsidy payment minus environmental damage) under the constraint that a certain level of profits accrues to the foreign investor. Let π^0 be this level of profits. The Lagrangean of the optimization problem is

$$L^i = tc_t q - s - d(a^{ii}c_t q) + \lambda(p(q/n)q - cq - f + s - \pi^0), \tag{10}$$

with λ as the shadow price. Maximization with respect to s yields $\lambda = 1$. Noting that $\partial\pi/\partial q = 0$ because of profit maximization, we obtain the optimal tax rate

$$t^i = a^{ii}d'. \tag{11}$$

The tax rate equals the marginal cost of environmental damage—that is, the emission tax is a Pigouvian tax. The reason for this result is that direct subsidies are the most efficient way to attract a foreign investor. If the same subsidy is given to the firm indirectly by means of a low emission tax, the increase in environmental damage is an additional cost component, which has to be taken into account by the policy maker. Therefore, lump-sum subsidies are better means to compete for a foreign investor.[8] Note, however, that the Pigouvian tax rate determined by equation (11) is not optimal; it is too high since it does not take into account the suboptimal output of the monopolist firm. The regulation of the monopolist remains a public-good problem in a world with many small countries.

Even transfrontier pollution does not change this result. The opportunity cost of being the host country is reduced since investment abroad would cause negative pollution externalities. But pollution coming across the border is independent of the government's choice of the tax rate since it is determined by the environmental policy in the other country only.

It is therefore exogenous to the country under consideration. Thus, the optimal policy is again to maximize net benefits at a target level of the investor's profits. The resulting optimal tax rate equals the domestic marginal environmental damage.

In the case of lump-sum subsidies, there will be no race to the bottom in environmental regulation. What about the not-in-my-backyard case? A lump-sum subsidy may be more efficient than an emission tax as an instrument to attract a foreign investor. But it cannot solve the free-rider problem of those who wish to appropriate the consumer surplus but do not want to bear the burden of hosting a polluting plant. Thus, the not-in-my-backyard case remains a possible outcome of the noncooperative game.

7. Final remarks

We have analyzed a very simple model of endogenous market structure and environmental-tax competition. It has been seen that there is a large variety of solutions ranging from a rat race with zero taxes to the chicken game and the case of not in my backyard. The deviations from jointly optimal policies can be substantial. Therefore, optimistic views of international tax competition that are based on competitive general-equilibrium models may turn out to be misleading if markets for environmentally intensive goods are noncompetitive.[9]

Of course, the model is simplistic in various respects. For instance, the endogeneity of market structure is modeled in a rather simple fashion: either no investment is undertaken, or a monopolist will run a single plant. Hoel (1994) has relaxed the assumption of a single firm and looked at the case of monopolistic competition, but the results do not change very much. Although there is a large number of firms, there is still only one host country in his model, and the structure of the game between the countries remains unchanged. Matters become more complicated if trade costs are introduced, when plants may be built in additional countries. As the paper by Markusen, Morey, and Olewiler (1992) has shown, such an extension fortifies its complexity even in the simple monopoly case, and one relies on numerical examples for a solution. Moreover, the present analysis has been simplified by assuming that the profits are earned by some foreign investor. This may be appropriate if one is interested in developing countries or small jurisdictions like communities. Hoel (1994) has looked at the more general case where shares of the profit accrue to the jurisdictions, and the results are similar to those obtained in this paper for the case of differing environmental damages.

Another striking simplification is the neglect of the rest of the economy. It has been assumed that the plant under consideration can be regulated individually. This may, however, result in discrimination against existing firms. Equal treatment of all firms may be required. If the tax rates for existing firms have been chosen subject to optimality criteria, a tax reduction to attract a new firm will cause deviations from the optimum and this generates welfare losses. A benevolent government should take these costs into account. This limits the potential for tax reductions, and a race to the bottom is slowed down. Finally, one may question the emphasis that is placed on tax revenue in this paper. Is tax revenue really so important that it can explain downward competition among environmental legislations? There are two replies to this. First, it may be true that green taxes do not generate a substantial tax revenue nowadays, but this may change. The current debate on the so-called double dividend, for instance, emphasizes the revenue-raising potential of environmental taxes. Green fees and taxes can be used to replace distortive taxes (for example, on labor income) and to generate the same tax revenue in a much less distortive manner (see Repetto, 1992, for instance). Second, even if green-tax revenues are not substantial, one could consider other benefits of foreign direct investments that may be more relevant in the political decision-making process. An obvious candidate is the reduction of unemployment. This could be modeled by the introduction of an additional variable into the welfare function or by the explicit consideration of the labor market. Like in the case of tax revenue, there would be a common-pool problem since only the host country can reduce its unemployment. Thus the structure of the game and the basic results would remain unchanged.

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Notes

1. Another kind of model is based on the idea of strategic trade policy where environmental policies are used to shift profits from the foreign to the home country. See Conrad (1993) and Barrett (1994). This may lead to inefficiently low emission taxes if the firm's strategic variables are quantities. These models, however, take the number of firms and their locations as given and therefore cannot be used to model interjurisdictional competition for mobile factors of production.
2. This result is not new. See Barnett (1980) for the optimal environmental tax rate in the standard monopoly model. The difference between the present model and the standard case is that here the profits go to foreigners and are not part of the social-welfare function.
3. Alternatively, one could also use a representation in terms of reaction functions, which would, of course, reveal the same results. In particular, it can be shown that Nash equilibria always exist, unlike in the tax competition model of Mintz and Tulkens (1986). Figure 3, however, appears to be more intuitive than a representation with reaction functions.
4. In order to fully characterize the game, something has to be said on its outcome if more than one country offers to be the host. It is assumed that in this case the monopolist throws dice and that the probability of becoming the host country is equally distributed. The payoff then is the expected welfare.
5. $t^3 > t^*$ because the consumer surplus is a declining function of the tax rate. Since global welfare contains n times the consumer surplus of a single country, the single country's welfare function has a larger slope than the global welfare function for any value of t.
6. Note that this would be a Nash equilibrium, however. There is a continuum of Nash equilibria between t^1 and the tax rate at which the net benefit of the country with the second-smallest pollution coefficient becomes zero. See Hoel (1994).
7. In a cooperative situation, the investment is desirable if $tr + (cs - d) > 0$. For a single country, the criterion is $tr + (cs - d)/n > 0$. It is obvious that the second condition is satisfied if the first one is satisfied but not vice versa.
8. This result is closely related to that derived by Oates and Schwab (1988): in a first-best world where the tax rate on foreign capital can be chosen optimally, environmental regulation is not used to attract capital.
9. Similar conclusions have been drawn by Ulph (1994) from policy simulations with a calibrated oligopolistic model.

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