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Environmental Regulation and the Location of Polluting Industries*

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 non-competitive 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.

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 domestic economy as a whole. In the long run, the firms that are affected by this policy 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

* I am indebted to Horst Siebert and Ingo Thomas for helpful comments.

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/Feiock* (1991), in contrast, come to the conclusion that environmental regulation does affect locational decisions of investors in the US chemical industry. The relationship found by *Rowland/Feiock* (1991) is highly non-linear: there is a threshold value of pollution-abatement costs below which dislocation effects of environmental-policy changes cannot be observed. *Hettige/Lucas/Wheeler* (1992) and *Lucas/Wheeler/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 seventies and eighties, when industrialised countries tightened their environmental standards. Similar results are reported by *Low/Yeats* (1992). Thus, one may conclude that there is some evidence that environmental regulation affects locational decisions but there are large differences in the responsiveness of different sectors towards environmental policy changes.

The second question whether the threat of delocation may lead to a disastrous competition among jurisdictions 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 which look at the economy as an aggregate. They are based on the traditional approach to international factor movements developed by *Jasey* (1960), *MacDougall* (1960), and *Kemp* (1964). Examples are the *Long/Siebert* (1991) and *Rauscher* (1994) models of international capital movements. It is shown there that welfare-maximising policy makers are not interested in undercutting foreign environmental taxes. Environmental policies may, however, be used to influence the remuneration of the mobile factor. The capital-rich country, striving for a high interest rate, prefers a lax environmental policy whereas the capital-poor country chooses a tough policy since this tends to reduce the world market rate of interest. Only if exogenous forces like lobbies are introduced, a rat race becomes feasible.
- On the other hand, there are partial-equilibrium models of non-competitive markets. One-country models of this type have been developed by *Markusen/Morey/Olewiler* (1993) and *Motta/Thisse* (1994). They generalise the *Brander/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 two countries by *Markusen/Morey/Olewiler* (1992) and *Ulph* (1994). They consider the jurisdictional competition explicitly. 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/Olewiler* (1992) have coined the term "not in my backyard". In this case, the number of polluting firms is smaller than the optimal one.

The present paper falls into the second category, that of non-competitive partial-equilibrium models. It uses a variant of the *Markusen/Morey/Olewiler* (1992) model which is simplified in some respects and more complicated in some others. *Markusen/Morey/Olewiler* (1992) consider a situation where there is one polluting firm which decides upon 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/Olewiler* (1992), 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.

The paper is organised as follows. The next section presents the model. Section 3 characterises 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. The final section summarises 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 non-competitive 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 which 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 which 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 this term encompasses all kind 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. Thus, the government of the hosting country is a Stackelberg leader vis-à-vis the monopolist. If governments do not co-operate, they play Nash against each other, and each country takes the environmental tax rates in the rest of the world as given. This game is solved in the usual backward fashion.

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 characterised 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 homogenous of degree one. The utilisation 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

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

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

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

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

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

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

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

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

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

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, i.e. where the firm makes a profit. If the emission tax is raised, the cost curves will be shifted upwards, 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.

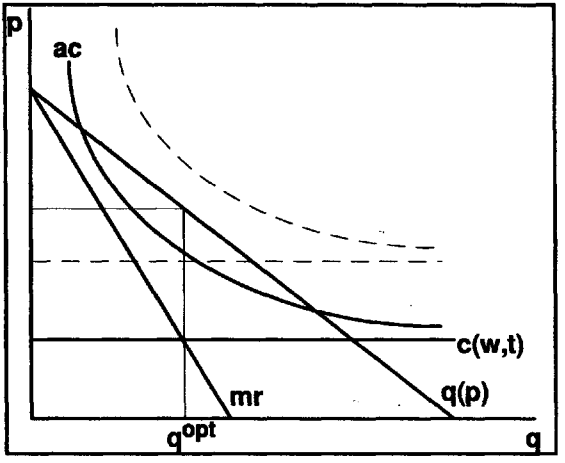

Figure 1: Behaviour of the monopolist

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

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

This formula states that the mark up 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.

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, e.g. in environmental concern. All these aspects are captured in a single parameter, a^{ij} (i,j=1,..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: tax revenues are appropriated by the host country. The other positive welfare component, which is equal for all countries however, is the utility derived from consumption, i.e. the consumer surplus. The welfare of the host country turns out to be

$$(6) \qquad w^i = -d(a^{ii}c_t q) + tc_t q + \int_0^{q/n} p(\varphi) - p(q/n)d\varphi$$

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

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

3. Coordinated environmental policies

If the countries coordinate their environmental policies, they maximise the total welfare, i.e. the sum of all w^i (i=1,...,n). A cooperative solution may require side payments in order to compensate potential losers. These need not be considered explicitly, since they are neutral 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

$$(8) \qquad (c_{tt}q + c_t\omega')\sum_{j=1}^{n} a^{ij}d' = c_t q + (c_{tt}q + c_t\omega')t - \frac{p' q\omega'}{n}$$

where country i is the host country. The left-hand side of this equation represents the marginal reduction in environmental damage due to an increase of the emission tax. On the right-hand side, there is the marginal cost of this tax increase. It consists of a change in the tax revenue and a reduction of consumer surplus.

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 $i,j,k,l,=1,...,n$). 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 $\sum_{j=1}^{n} a^{ij}$ is minimised should host the firm.

For the general case where the a^{ij} differ across countries, an explicit solution of the optimisation problem is impossible.

The policy determined by equation (8) is not the best policy. There are two distortions in the model, an environmental externality and the non-competitive market structure. A truly optimal policy would require additional policy instruments.[1] This is, however, not the subject of the analysis in this paper.

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

$$(c_{III}q + 2c_{II}\omega' + c_I\omega'')\sum_{j=1}^{n} a^{ij}d' + (c_{II}q + c_I\omega')\sum_{j=1}^{n}\left(a^{ij}\right)^2 d''$$

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1 An optimal policy would emulate a competitive market by setting an upper bound of the price such that it equals the marginal cost. In this case, the monopolist has to be supported by a lump-sum subsidy equalling the fixed cost. An emission tax rate serves the purpose of internalising the environmental externalities. The optimal tax formula would resemble equation (8). However, ω' would be different since $dq/dt = nc_I/p'$. Under normal circumstances, this first-best policy would be characterised by a higher tax rate than the second-best policy. If the monopolist is allowed to behave like a monopolist, she saves environmental resources by restricting her output. If the monopolist's power is reduced by government intervention, the emission tax rate has to be raised.

and its sign is indeterminate in the general case. If, however, the production function is Cobb-Douglas and the demand function is linear, then $c_{tt}>0$ 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 large tax rate. This is the Laffer-curve property. The second derivative is

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

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.

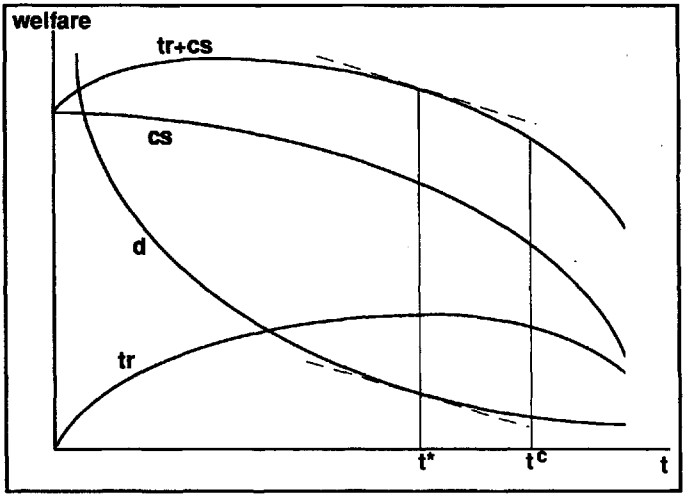

Figure 2: Optimal environmental policy

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, i.e. $t^*<t^c$.

4. Non-cooperative environmental policies

Now consider a situation in which the n countries compete for the foreign investor. For the sake of simplicity, we will 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.

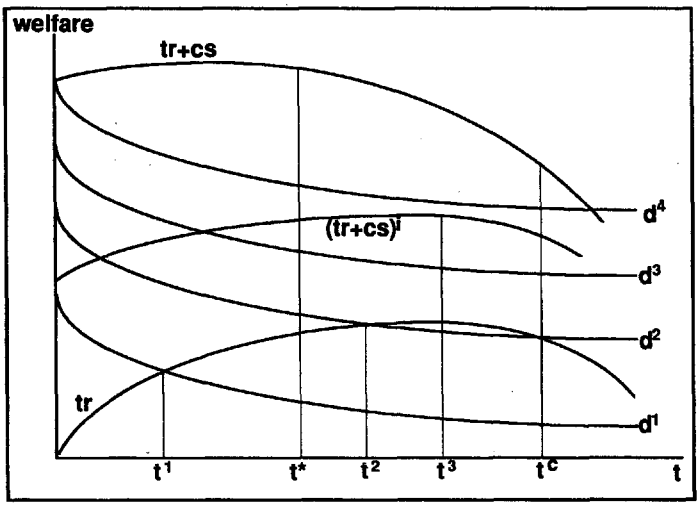

Figure 3: Jurisdictional competition

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 upwards, 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.

Consider first a scenario in which each country (correctly) conjectures that there will be someone who will host the polluter. In this case, the consumer surplus accrues 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 these situation, each country is better off if 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, i.e. at tax level of t^1. This is the case of a rat race. Jurisdictional competition results in under-regulation 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.[2] The host country is the chicken. This game has n pure-strategy equilibria and it is not clear

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2 In order to fully characterise the game, something has to be said on the outcome of the game 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.

whether one of them will be attained. See *Fudenberg/Tirole* (1991, 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 maximises its national welfare, i.e. $(tr+cs)^i$-d. It is too high.[3] It should be noted that the relationship between environmental damage and the emission tax is non-monotonous. 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 prisoners' 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/Olewiler* (1992) paper.

Two effects generate the deviation from the desirable environmental policy. On the one hand, the host country appropriates the tax revenue. If this is large compared to the environmental damage, the jurisdictional competition will induce the governments to undercut tax rates imposed elsewhere. On the other hand, there is the consumer surplus of which the home country can appropriate only one nth. This generates the potential for a prisoners' dilemma 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 which is undesirable, will never be made. This result may, however, be changed if transfrontier pollution is introduced.

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3 $t^3>t^*$ 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.

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, i.e. if $a^{ii} \neq a^{jj}$ 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 non-negative. This is efficient since the polluting plant should be located where the environmental cost is minimised. 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 will never be rational to reduce the tax rate towards the level at which the net benefit vanishes. Thus, the tax rates offered by the country are larger than t^1 and t^2, respectively. There will be a tendency towards larger tax rates. Of course, the cases of the chicken game and the prisoners' 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.[4] The jurisdictional competition now takes the following shape. The opportunity cost of undercutting foreign tax rates

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[4] 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.

becomes infinitesimally small. Like the consumer surpluses 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 towards 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 towards zero regulation, it is assumed that each country is the main source of its own pollution, i.e the diagonal elements of the transfrontier-pollution matrix dominate the other elements in each column ($a^{ii}>a^{ij}$ 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} ($j=1,...,n$) is minimised. 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 characterised by

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

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 backyard 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 nearly 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. Final remarks

We have analysed 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 non-competitive. [5]

Of course the model is simplistic in various respects. For instance the endogeneity of market structure is modelled in a rather simple fashion: either no investment is undertaken or a monopolist will run a single plant. However, as the paper by *Markusen/Morey/Olewiler* (1992) has shown, even a small extension of the model by adding an additional plant fortifies its complexity and one relies on numerical examples for a solution. Another simplification of the model is the consideration of environmental taxes as the only policy instrument. This may be appropriate when jurisdictions are concerned that have some discretion in their environmental policy but no sovereignty in other issues. A really sovereign jurisdiction should, however, take other possibilities into account. There is more than one distortion in the model and a welfare-maximising policy, therefore, requires more than a single policy instrument. Extensions of the model into this direction are desirable. Finally one may question the emphasis which is placed on tax revenue in this paper. There are two

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5 Similar conclusions have been drawn by *Ulph* (1994) from policy simulations with a calibrated oligopolistic model.

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, emphasises the revenue-raising potential of environmental taxes. At the moment, tax revenues are generated predominantly by distortive taxes (e.g. on labour income). Green fees and taxes may be used 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 example is the reduction of unemployment. This could be modelled by the introduction of an additional variable into the welfare function or by the explicit consideration of the labour market. The basic results, however, would the same as in the case of tax revenues.

References

Bartik, T.J., 1988, The Effects of Environmental Regulation on Business Location in the United States, *Growth and Change* 19, 22-44.

Brander, J.A., P.R. Krugman, 1983, A Reciprocal Dumping Model of International Trade, *Journal of International Economics* 15, 313-321.

Fudenberg, D., J. Tirole, 1991, *Game Theory*, Cambridge (Mass.): MIT-Press.

Hettige, H., R.E.B. Lucas, D. Wheeler, 1992, The Toxic Intensity of Industrial Production: Global Patterns, Trends, and Trade Policy, *American Economic Review (Papers and Proceedings)* 82, 478-481.

Jasay, A.E., 1960, The Social Choice between Home and Overseas Investments, *Economic Journal* 70, 105-113.

Kemp, M.C., 1964, *The Pure Theory of International Trade*, Englewood Cliffs: Prentice Hall.

Leonard, H. J., 1988, *Pollution and the Struggle for the World Product: Multinational Corporations, Environment and International Comparative Advantage*, Cambridge: Cambridge University Press.

Long, N.V., H. Siebert, 1991, Institutional Competition versus Ex-ante Harmonization: The Case of Environmental Policy, *Journal of Institutional and Theoretical Economics* 147, 296-311.

Low, P., A. Yeats, 1992, Do Dirty Industries Migrate?, in: P. Low, ed., *International Trade and the Environment*, New York: World Bank Discussion Paper No. 159, 89-103.

Lucas, R.E.B., D. Wheeler, H. Hettige, 1992, Economic Development, Environmental Regulation, and the International Migration of Toxic Industrial Pollution: 1960-1988, in: P. Low, ed., *International Trade and the Environment*, New York: World Bank Discussion Paper No. 159, 159-167.

MacDougall, G.D.A., 1960, The Benefits and Costs of Investment from Abroad. A Theoretical Approach, *Economic Record* 36, 13-35.

Markusen, J.R., E.R. Morey, N. Olewiler, 1992, *Noncooperative Equilibria in Regional Environmental Policies when Plant Locations Are Endogenous*, Cambridge, MA: NBER Working Paper No. 4051.

Markusen, J.R. E.R. Morey, N. Olewiler, 1993, Environmental Policy when Market Structure and Plant Locations Are Endogenous, *Journal of Environmental Economics and Management* 24, 68-86.

Motta, M., J.-F. Thisse, 1994, *Does Environmental Dumping Lead to Delocation?*, Milan: Fondazione ENI Enrico Mattei Discussion Paper No. 9415.

Rauscher, M., 1994a, Environmental Policy and International Capital Movements, forthcoming in: K.-G. Mäler, *International Environmental Problems: An Economic Perspective*, Amsterdam: Kluwer.

Repetto, R., 1992, *Green Fees: How a Tax Shift Can Work for the Environment and the Economy*, Washington, DC: World Resources Institute.

Rowland, C.K., R. Feiock, 1991, Environmental Regulation and Economic Development: The Movement of Chemical Production among States, in: M.J. Dubnick, A.R. Gitelson, eds., *Public Policy and Economic Institutions*, Greenwich (Conn.): JAI Press, 205-218.

Ulph, A., 1994, Environmental Policy, Plant Location and Government Protection, forthcoming in: C. Carraro, ed., *Trade, Innovation, Environment*. Rotterdam: Kluwer.

Walter, I., 1982, Environmentally Induced Industrial Relocation to Developing Countries, in: S.J. Rubin, T.R. Graham, eds., *Environment and Trade: The Relation of International Trade and Environmental Policy*, Totowa, NJ: Allanheld and Osmun, 67-101.