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Abstract

The purpose of the paper is to outline an analytical framework which captures the ample scope of locational competition: cost differences, resulting from differences in factor prices including taxes, human capital, infrastructure services and total factor productivity. If cost differences are small, locational competition controls excessive government power. We have modeled locational competition by assuming that governments have a vital interest to keep mobile factors of production at home. We represent this aspect by restricting the usage of environmental instruments such that they will at most exhaust the cost difference to a competing foreign firm. If cost differences are large enough there is no binding restriction for the cost-benefit calculus of a national environmental policy. The tax will be below marginal damage due to strategic reasons of rent shifting. If small international cost differences do not allow taxation in accordance with marginal damage considerations, then locational competition restricts the size of the tax rate such that the firm is indifferent in relocating or staying at home. If no cost differences exist, it is even possible that both governments will subsidize the pollution intensive input in order to make the domestic location attractive.

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1. Introduction

It is argued in the literature that differences in environmental regulations are an important factor in industrial location (industrial flight hypothesis). This hypothesis is derived from an extension of the Heckscher-Ohlin model of comparative advantage. Since companies can avoid regulations by locating abroad, free trade erodes the independence of a country in implementing an environmental policy. This exerts a strong pressure towards lax regulation in order to signal a pollution haven to producers. Especially in the theoretical literature, multinational firms seem to base their direct foreign investment decision or plant location upon the stringency of environmental regulation in other countries (developing countries or Eastern Europe). The environmental regulation intensity is expected to be a significant determinant of competitiveness and causes industrial flight from developed countries. The argument is that stringent environmental standards cause high costs of production, leading to a decline in competitiveness, and ultimately in market share, jobs and investments. In countries with persistently high unemployment, threats of job losses and of plant relocation can be very powerful and helpful for opponents of a strict environmental policy.[1] However, a broad consensus has emerged in the empirical literature that regulatory differences (with some exceptions) have, at best, a negligible impact on industrial location. Studies attempting to measure the effect of environmental regulation on net exports, overall trade flows, and plan-location decisions have produced estimates that are either small or statistically insignificant. These results emerged from studies by Jaffe et al. (1995) and Adams (1995) which review the empirical evidence.

We therefore will specify a model which permits the **option** to relocate but in which governments will not set environmental taxes or standards such that firms will choose this option. In this model location decisions do not only depend on regulatory differences, but also on differences in factor prices, in the quality of the labor force, access to markets, differences in corporate taxes or in the provision of infrastructure. Governments know these factors which can affect business location decisions and they also know that it is rather unlikely that firms

[1] See Jaffe et al. (1995) and Adams (1995) for excellent surveys on environmental regulation and competitiveness.

will move to another country for the only reason of taking advantage of relatively lax environmental standards.

The purpose of this paper is to introduce international productivity gaps into a model on relocation decisions and to show that there is plenty of room for strict regulation if countries are not too similar in terms of productivity and factor price differences. With productivity gaps between countries, it is hopeless to lure business into another country by providing low environmental standards. In our special model, governments might exploit the cost advantage of their domestic firms to a certain extent by adding an environmentally motivated regulatory burden, but they will set this burden low enough such that it will not cause firms to relocate existing plants. Therefore this model is in line with a study by Bartik (1988) who found that air and water pollution control expenditures, costs of compliance, and allowed particulate emissions all have an insignificant effect on plant location decisions. Jaffe et al. (1995) summarize the reasons why the effects of environmental regulation on location decisions may be small. First, for all but the most heavily regulated industries, the cost of complying with environmental regulation is a relatively small fraction of total cost of production. Second, labor cost differentials, energy and raw materials cost differentials and infrastructure adequacy dominate the environmental cost effect. Third, other monetary-equivalent costs or benefits like public services, unionization of a country's labor force, or agglomeration effects from the existing level of manufacturing activity in a region also affect plant location choices. Fourth, since the difference in environmental regulation in western industrial countries is not large, the incentive to relocate is small. And fifth, in case significant differences in regulatory stringency exist, firms may not exploit them. Because of environmental credibility reasons firms are reluctant to build less-than-state-of-the art plants in foreign countries, or, when environmental standards are relatively weak, firms may invest more in pollution control than is required.

We will now give a short survey of the literature. The first model on location decision and environmental policy is by Markusen, Morey and Olewiler (1993). They develop a model that allows firms to enter or exit, and to change the number and locations of their plants in response to changes in environmental policies. There are increasing returns at the plant level (fixed costs), imperfect competition between a domestic and a foreign firm, and transport costs of shipping out between two markets. The authors consider two countries and assume that one firm - not yet established at the beginning of the game - is associated with each country. Firms decide where to set up production after having observed the governments' move. The decision to serve another region is a discrete choice between the high fixed-cost option of a foreign branch plant or the high variable-cost option of exporting to that market. Decisions on plant locations are no longer based on marginal analysis but are now discrete choice problems. At critical levels of environmental policy variables, small policy changes cause large discrete jumps in a region's pollution and welfare as a firm closes or opens a plant, or shifts production to/from a foreign branch plant. They extend their model by introducing tax competition between the governments of the two regions (Markusen, Morey and Olewiler (1995)). If the damage from pollution is high enough, the two governments will compete by increasing their environmental taxes until the polluting firm is driven from the market. Alternatively, if damage from pollution is not as high, the governments will compete by undercutting each other's pollution tax rates. Markusen et al. (1995) use numerical examples that show the range of parameters that cause a move from one equilibrium to another. Following them, Hoel (1997) also considers a two-stage game at the firm and at the government level. Under his assumption that costs of the firms, except taxes, are independent of where the firms locate, each firm will only produce in one (or none) of the two countries. Markusen et al. (1995) allow for non-zero transportation costs which implies that it may be optimal for a firm to locate in both countries in spite of its fixed costs. Hoel's somewhat simpler model makes it possible to derive some qualitative results under rather general assumptions. In the game he considers the governments of the two countries first choose their tax rates, after which the firm locates in the country with the lowest tax rate. Markusen et al. and Hoel analyze the case where environmental damage is so large that the firm does not locate in any of the countries in the Nash equilibrium (the NIMBY case (not in my backyard)). The main conclusion from the model is that the incentive of each country to attract firms results in lower environmental taxes than it would be with cooperation. The model by Rauscher (1995) is another simplified version of Markusen et al. (1995) by neglecting transportation costs so that a single plant suffices to serve the whole market. In this paper there is one firm that wishes to establish a plant in one of *n* countries and the game between the countries is affected by transboundary pollution effects. It has been shown that there is a large variety of taxes ranging from zero taxes to taxes as high as to imply the NIMBY case. In Ulph (1994), several producers of a single industry have to decide where to locate plants to serve several markets. In a multi-stage game governments first choose their policies to restrict emissions of a pollutant (no strategic policy), producers then make location decisions and finally set outputs. In the paper the question is considered whether governments should offer subsidies to producers to prevent them from relocating to other countries. A rebate policy of taxes back to the industry is simulated using data for the world fertilizer industry. Ulph wants to demonstrate that relocation can change the degree of competitiveness of different markets. Producers have chosen to locate where there are economies of agglomeration so that moving into foreign markets sacrifies some of these economies. The trade-off between these economies and transport costs will be one of the factors affecting firms in their choice of plant location.

In Motta and Thisse (1994) firms are already established in their home country when the game begins. They study the impact of the home country's environmental policy on the domestic firm's location while the foreign firm's location strategy is given. The option for the domestic firm is to supply both markets from its domestic plant; or to establish a second plant in the foreign market; or to shut down the home plant and to serve both markets through the new plant set up in the foreign country. Exports imply transportation costs and environmental policy that raises marginal cost. They describe the equilibrium configurations by a partition of the parameter space. The objective is to show that environmental trade barriers may cause significant welfare losses.[2]

Location decisions of footloose firms in response to environmental costs are also analyzed in Markusen (1999), who presents simulation results derived from a numerical general equilibrium model. In summarizing the results from the main contributions to the location topic he emphasizes that it is not at all clear that regional competition for mobile plants leads to lower standards in equilibrium.

The last two papers look at location decision but not in an environmental context. Venables' (1996) paper deals with location choice and agglomeration. He demonstrates that even without labor mobility there are forces leading to agglomeration of activities at particular locations in an integrated region. Production occurs in both locations when transport costs are high (firms are tied to markets and their location decisions are much less sensitive to production costs. In his upstream-downstream industry structure, production also occurs in

[2] Two recent discussion papers on strategic location decisions are Petrakis and Xepapadeos (2000) and Greaker (2000). The former analyze delocation decisions of a monopolist who faces an emission tax in the home country. The latter look at the strictness of strategic environmental policy when the governments are bounded by the treat of regulation.

both locations when transport costs are low (factor prices then determine location). The paper focuses on intermediate transport costs and multiple equilibria. The paper by Markusen and Rutherford (1994) introduces discrete location choices in a general equilibrium approach. In their model one firm is allowed to endogenously choose among 15 alternative plant-location configurations. The other firms retain their existing numbers of and locations for their plants, but endogenously adjust their outputs, markups, and shipment patterns. The focus is on the North American auto industry in the NAFTA context.

Our paper is organized as follows. In section 2 we introduce the concept of productivity differences between countries as originated by Jorgenson and Nishimizu (1978), and derive a maximal environmental tax which could offset the productivity advantage of an industry making it indifferent between staying or relocating. In section 3, we introduce imperfect competition between domestic and foreign firms which differ in terms of factor prices and total factor productivity. Depending on the difference in the cost of production, they decide about the siting of their plants. In section 4, we introduce environmental tax competition between two governments where by each government is concerned about industrial migration in response to differentials in environmental taxes. In section 5, we extend our basic model by introducing fixed set up costs for relocating existing plants, and by analyzing an environmental tax competition, where each government wants to attract domestic as well as foreign firms by a less stringent environmental policy. Section 6 summarizes our conclusions.

2. Location Decisions under Differences in Factor Prices and in Total Factor Productivity

We assume that a firm produces the quantity x of output with labor and energy and is flexible in making the decision about the site of its plant. Let D_{-1} be a vector $D_{-1} := (D_2, D_3, ..., D_n)$ with $D_j = 1$ if industry 1 is located in country $j \neq 1$ and 0 otherwise where country 1 is the base country. Additionally let q_{L_j} denote the price of labor in country j. With country 1 as the base country the price of labor q_L actually paid by the firm is a function of the location decision and the price differences with respect to the base country 1 are

(1) $$q_L = q_L(D_{-1}) \quad \text{and} \quad \frac{d\,q_L}{d\,D_j} = q_{L_j} - q_{L_1}\,.$$

Similarly, let the price of energy be

(2) $$q_E = q_E^0(D_{-1}) + t_E(D_{-1}) \cdot e \quad \text{with} \quad \frac{d\,q_E}{d\,D_j} = q_{E_j} - q_{E_1} + (t_j - t_1) \cdot e$$

where e is an emission coefficient, e.g. for CO_2, and t_j is an emission or energy tax which differs country-wise. The joint cost function then is

(3) $$C = C(x, q_L, q_E, D_2, \ldots, D_n)$$

with D_j as the dummy variable for country j. The differences in regional cost functions are maintained by the additional argument D_{-1} in the cost function. If

(4) $$\frac{\partial C}{\partial D_j} > 0 \qquad \text{(given } q_L, q_E \text{ and } x\text{)}$$

then relocation from the base country 1 to country j will result in higher costs of production due to lower productivity in country i. The opposite holds if $\frac{\partial C}{\partial D_j} \leq 0$.[3]

The total difference in costs if the firm migrates from country 1 to country j is

(5) $$\frac{d\,C}{d\,D_j} = \frac{\partial C}{\partial x} \cdot \frac{d\,x}{d\,D_j} + L_1 \cdot \frac{d\,q_L}{d\,D_j} + E_1 \left(\frac{d\,q_E^0}{d\,D_j} + \frac{d\,t}{d\,D_j} \cdot e \right) + \frac{\partial C}{\partial D_j}$$

[3] In principle, (4) is a definition since D_j is a discontinuous variable and thus cannot be used to form a partial derivative. Denny and Fuss (1983) showed that if we had ignored the fact that D_j is discontinuous, and differentiated C with respect to it we would have obtained a function of a partial derivative defined as such before.

where $\frac{\partial C}{\partial q_L} = L_1$, $\frac{\partial C}{\partial q_E} = E_1$ has been used (Shephard's Lemma). If $\frac{d\,C}{d\,D_j} \geq 0$ for all j, then the firm will stay in the base country 1. If $\frac{d\,C}{d\,D_j} < 0$ for some j, then the firm will migrate to country $j_0 = \underset{j \in I}{\operatorname{argmin}} \frac{d\,C}{d\,D_j}$, $I = \{2,3,...,n\}$. According to (5), differences in labor costs, in energy costs, in environmental regulation and differences in total factor productivity (TFP) are determinants for a decision to relocate. We have not yet introduced relocation costs or transportation costs. Differences in infrastructure services, human capital, or R&D activities are included in the TFP difference term or could be an additional term in the cost function.[4] Since we are interested whether **new** environmental regulations will cause the firm to relocate the existing plant, we assume that the firm produces in country 1, i.e., it is $\frac{d\,C}{d\,D_j} \geq 0$ for all j.

Therefore our approach emphasizes not only differences in factor prices and in environmental policy, but especially differences in national productivity. The next step is to introduce imperfect competition and environmental policy regulation in order to model the strategic interdependency of location decisions by firms and environmental policies by governments.

3. Location Decisions and Imperfect Competition

We suppose there is a single firm in each of two countries which operates only one plant to serve the entire world market. We assume that each unit energy used produces one unit of pollution (i.e. e = 1), and that there is no abatement technology. Pollution affects only the country in which the plant is located, and government in each country imposes an emission or energy tax. The structure of the moves will be that the two governments first commit themselves to a level of emission tax; then the firms decide to stay or to relocate. Besides ecological dumping as a lax environmental policy to stabilize market shares of the domestic

[4] If $C = C(x, q_L, q_E, KI, D_2, ..., D_n)$ where KI is infrastructure, then an additional cost difference enters in (5), namely $\frac{\partial C}{\partial KI}\frac{d\,KI}{d\,D_j}$ where $\frac{\partial C}{\partial KI} < 0$ is the reduction in costs from a marginal increase in infrastructure.

firm, there is additional pressure on governments to relax their environmental policies if plants are able to relocate. We assume that the production process is the same in both countries but that factor prices and TFP differ. The corresponding fixed costs are sunk when the game begins. Hence firm 1(F1) and firm 2 (F2) do not have to take into account any fixed cost when they operate their domestic plant in country 1 or 2. We therefore follow the approach of Motha and Thisse (1994) by assuming that firms are already established in their home country when the game begins. When firms are already established in their home country, setting up a plant abroad involves fixed set-up costs which have already been sunk in the domestic plant. With fixed set-up costs F_1, profit of the home firm 1, F1, is

(8) $$p_1 = p(x_1 + x_2)\,x_1 - C(x_1, q_L(D_2), q_E(D_2), D_2) - F_1 \cdot D_2 .$$

Profit of the foreign firm 2, (F2), is

(9) $$p_2 = p(x_1 + x_2)\,x_2 - C(x_2, q_L(D_1), q_E(D_1), D_1) - F_2 \cdot D_1$$

Factor prices for F1 are:

(10) $q_L(D_2) = q_{L_1} + (q_{L_2} - q_{L_1}) \cdot D_2$, and $q_E(D_2) = q_{E_1} + t_1 + \big((q_{E_2} - q_{E_1}) + (t_2 - t_1) \cdot e\big) \cdot D_2$.

We assume that country 1, C1, the home country, is the country with lower factor prices and hence lower TFP, i.e., $\frac{d\,q_k}{d\,D_2} > 0,\ k = L, E$. If F1 produces in C1 $(D_2 = 0)$, then factor prices are q_{L_1} and $q_{E_1} + t_1$, and they are higher if F1 produces in C2 $(D_2 = 1)$.

In our two country case, the factor prices for F2 are:

(11) $q_L(D_1) = q_{L_2} - (q_{L_2} - q_{L_1}) \cdot D_1$, and $q_E(D_1) = q_{E_2} + t_2 - \big((q_{E_2} - q_{E_1}) + (t_2 - t_1) \cdot e\big) D_1$

F2 produces in C2 $(D_1 = 0)$ at higher factor prices and pays less for the factors if it relocates $(D_1 = 1)$. FOCs for our duopoly are:

(12) $$MR_1(x_1, x_2) = MC(x_1, q_L(D_2), q_E(D_2), D_2)$$

(13) $$MR_2(x_1, x_2) = MC(x_2, q_L(D_1), q_E(D_1), D_1).$$

We assume constant returns to scale, $C(\cdot) = x_i \cdot c(\cdot)$, and rewrite (12) and (13) as

(12’) $$MR_1(x_1, x_2) = c(q_L(D_2), q_E(D_2), D_2)$$

(13’) $$MR_2(x_1, x_2) = c(q_L(D_1), q_E(D_1), D_1).$$

Each firm does not migrate if marginal profit decreases after migration, i.e.,

$$\frac{d\,p_i}{d\,D_j} \leq 0 \qquad \text{or} \qquad \frac{d\,p_i}{d\,D_j} = \frac{\partial\,p_i}{\partial\,x_i}\frac{d\,x_i}{d\,D_j} + \frac{\partial\,p_i}{\partial\,x_j}\frac{d\,x_j}{d\,D_j} - x_i\frac{d\,c(\cdot, D_j)}{d\,D_j} - F_i \leq 0.$$

Since the first term is zero (FOC), and the second term also because of a Cournot type reaction hypothesis that firm j will not change its output level if firm i relocates (i.e. $d\,x_j / d\,D_j = 0$), the condition for non-migration is:

(14) $$\frac{d\,c(\cdot, D_j)}{d\,D_j} + \frac{F_i}{x_i} \geq 0 \qquad \text{or} \qquad \frac{d\ln c(\cdot, D_j)}{d\,D_j} + s_{F_i} \geq 0 \qquad (i \neq j)$$

where $s_{F_i} = \frac{F_i}{x_i \cdot c_i}$ is the cost share of the set-up costs with $c_i = c(q_{L_i}, q_{Ei} + t_i)$. Because of Shephard’s lemma, total differentiation of $c(\cdot)$ yields

(15) $$\frac{d\ln c}{d\,D_j} = \frac{q_{L_i} \cdot L_i}{x_i \cdot c_i}\frac{d\ln q_L}{d\,D_j} + \frac{(q_{E_i} + t_i)E_i}{x_i \cdot c_i}\frac{d\ln q_E}{d\,D_j} + \frac{\partial \ln c}{\partial\,D_j}.$$

For the rate of country-wise difference in total factor productivity we assume

$$\frac{\partial \ln c}{\partial D_2} < 0 \qquad \text{and} \qquad \frac{\partial \ln c}{\partial D_1} > 0 .$$[5]

An unit of output, produced by F1 in C2 instead of in C1, can be produced at lower costs because of higher TFP, given factor prices from C1. An unit of output, produced by F2 in C1 instead of in C2, will be produced at higher costs by the same rate because TFP is lower by that rate, given factor prices from C2. For firm *i*, the decision to relocate depends on the sign of the difference in total costs:

(16) $$\frac{d \ln c}{d D_j} + s_{F_i} = s_{L_i} \frac{d \ln q_L}{d D_j} + s_{E\,t,i} \frac{d \ln q_E}{d D_j} + \frac{\partial \ln c}{\partial D_j} + s_{F_i}$$

where $s_{L_i} = \frac{q_{L_i} \cdot L_i}{x_i \cdot c_i}$ and $s_{E\,t,i} = \frac{(q_{E_i} + t_i) E_i}{x_i \cdot c_i}$

are the cost shares of labor and of energy. Following Jorgenson and Nishimizu (1978), the productivity term can be calculated as a residual:

(17) $$\frac{\partial \ln c}{\partial D_j} = \frac{d \ln c}{d D_j} - \sum_{k=L,E} \bar{s}_k \frac{d \ln q_k}{d D_j}$$

where $\bar{s}_k$ are the average cost shares of the two countries.

There are four possible market structures:

Case (1,2): F1 stays in C1, F2 stays in C2:

(18) $$\frac{d \ln c}{d D_j} + s_{F_i} \geq 0 \qquad \text{or} \qquad s_{L_i} \frac{d \ln q_L}{d D_j} + s_{E\,t,i} \frac{d \ln q_E}{d D_j} + s_{F_i} \geq - \frac{\partial \ln c}{\partial D_j} .$$

For F1, the weighted increase in factor prices when relocating plus the set-up cost share is larger than the cost saving from higher productivity. For F2, the weighted saving in lower

[5] In the discrete variable case, $\frac{\partial \ln c}{\partial D_2}$ is approximated by $\frac{1}{2}\left(\left.\frac{\partial \ln c}{\partial D_2}\right|_{D_2=0} + \left.\frac{\partial \ln c}{\partial D_2}\right|_{D_2=1} \right)$.

factor prices net of the set-up cost share is less than the home advantage of higher productivity when relocating.

Case (2,2): F1 migrates to C2, F2 stays in C2.

$$\frac{d\ \ln c}{d\ D_2} + s_{F_1} < 0\,, \qquad \frac{d\ \ln c}{d\ D_1} + s_{F_2} \geq 0\,.$$

For F1, this is equivalent to

$$(19) \qquad s_{L_1}\frac{d\ \ln q_L}{d\ D_2} + s_{Et,1}\frac{d\ \ln q_E}{d\ D_2} < -\left(\frac{\partial\ \ln c}{\partial\ D_2} + s_{F_1}\right).$$

F1 migrates because the productivity advantage in C2 net of the set-up cost share justifies the higher factor prices which have to be paid there.

Case (1,1): F1 stays in C1, F2 migrates to C1.

$$\frac{d\ \ln c}{d\ D_2} + s_{F_1} \geq 0\,, \qquad \frac{d\ \ln c}{d\ D_1} + s_{F_2} \leq 0\,.$$

For F2, this is equivalent to

$$(20) \qquad s_{L_2}\frac{d\ \ln q_L}{d\ D_1} + s_{Et,2}\frac{d\ \ln q_E}{d\ D_1} < -\left(\frac{\partial\ \ln c}{\partial\ D_1} + s_{F_2}\right).$$

F2 migrates because the cost savings due to lower factor prices in C1 (the left hand side of (20) is negative by assumption) more than compensates the costs which incur when the firm migrates, i.e. lower TFP in C1 and set-up costs.

Case (2,1): F1 migrates to C2, F2 migrates to C1.

$$(21) \qquad \frac{d\ \ln c}{d\ D_2} + s_{F_1} < 0\,, \qquad \frac{d\ \ln c}{d\ D_1} + s_{F_2} < 0\ .$$

F1 leaves the low cost country because higher factor prices including the set-up cost share are more than compensated by the higher TFP in C2. F2 in turn leaves the high cost country because lower factor prices in C1 more than compensate for the disadvantage of the low TFP in addition to the set-up cost burden.[6]

Since the production technology is by assumption the same, case (1,1) and case (2,2) yield symmetric Nash equilibria because both firms produce with the same productivity at the same factor prices. The case (2,1) is not an equilibrium because after migration each firm produces at conditions identical to those of the firm which migrated because of these conditions. It would therefore return to its previous location; i.e. it would stay there.[7] In addition, if both firms would migrate, the reaction hypothesis, that the other firm's output is constant, would be inconsistent. But if only one firm migrates, this reaction hypothesis is consistent. Finally, not to relocate yields an asymmetric Nash-equilibrium.

For an empirical implementation of our approach it might be useful to consider a joint cost function with variable cost shares. A specification, used in analyzing differences in international productivities, is a translog function. It is linear and quadratic in factor prices and output, and the assumption on the joint cost function is that the parameters for the quadratic terms are country-wise not different but the parameters for the linear terms are. This implies that cost shares depend on relative prices with common parameters for their impact on the shares, and on a constant which differs country-wise. Since the elasticities of substitution by Allen or Morishima depend on the cost shares, they will be different under a translog joint cost function. The condition (18) for no relocation can then be satisfied even if there are no fixed set-up costs. It is equivalent to

$$s_{L_1}\frac{d\ln q_L}{d\,D_2}+s_{Et,1}\frac{d\ln q_E}{d\,D_2}+s_{F_1}\geq-\frac{\partial\ln c}{\partial D_2}\geq s_{L_2}\frac{d\ln q_L}{d\,D_2}+s_{Et,2}\frac{d\ln q_E}{d\,D_2}-s_{F_2}\,.$$

Differences in the arithmetic mean of the change in factor prices with cost shares as weights can be a reason for different locations. If the price of energy is higher in country 2, but s_{E_2} is less than s_{E_1} due to good substitution possibilities, then it is not a location disadvantage to

[6] Condition (21) can only be satisfied if cost shares and relative prices differ very much.

[7] If fixed costs are firm specific, that is, they are independent from the joint production technology, then a relocation of both firms can yield an equilibrium.

stay in the high cost country. Finally, the higher the fixed cost share, the more likely it is that (22) holds.

4. Tax Competition without Causing Relocation

The government of C1 maximizes welfare with respect to an emission tax t_1 where welfare is the sum of profit and "environmental surplus" (tax revenue minus damage DA):[8]

$$(22)\qquad \max_{t_1}\; w_1 = p(x_1 + x_2)x_1 - x_1 \cdot c\left(q_L(D_2), q_E^0(D_2) + t(D_2), D_2\right) + t_1 \cdot E(D_2) - DA_1(E(D_2))$$

subject to the condition that the domestic firm F1 does not relocate, i.e.

$$(23)\qquad \frac{d \ln c}{d\, D_2} + s_{F_1} = s_{L,1}\frac{d \ln q_L}{d\, D_2} + s_{E,1}\frac{d \ln q_E^0}{d\, D_2} + s_{t,1}\frac{d \ln t}{d\, D_2} + \frac{\partial \ln c}{\partial\, D_2} + s_{F_1} \geq 0$$

where $s_{E,1} = \frac{q_{E_1} \cdot E_1}{x_1 \cdot c_1}$, and $s_{t,1} = \frac{t_1 \cdot E_1}{x_1 \cdot c_1}$.[9] We assume that (23) was satisfied before the introduction of an emission tax or of a tax increase. The home government can then raise t_1, implying $d^2 t / d\, D_2 d\, t_1 < 0$, until the cost disadvantage when relocating is exhausted. Since (23) is satisfied, i.e. F1 stays in C1, D_2 is equal to zero in the objective function, i.e.

$$(24)\qquad \max_{t_1}\quad w_1 = p(x_1 + x_2)x_1 - x_1 \cdot c(q_{L_1}, q_{E_1} + t_1, D_2 = 0) + t_1 \cdot E_1 - DA_1(E_1) \qquad \text{s.t. (25)}$$

It is argued that the drawback of a measure of welfare used is that it does not account for possible job losses associated with a partial or total delocation (Motta and Thisse (1994)). I personally would, however, interpret profit not as a tax base for the government or as an income flow to the shareholders but positive profits as a signal that a firm exists which creates jobs. If a firm makes profit abroad, it is irrelevant for the welfare measure to add a term which

[8] In principle, the total value of the objective function has to be multiplied by $(1 - D_1)$ because if the firm moves to C2, welfare in C1 is zero.
[9] (23) follows from (15) and (16).

represents the percentage of repatriated profit (e.g. Motta and Thisse (1994)). If a firm delocates, jobs are lost which is more important for the country than lost profit. Our restriction (23) expresses the interest of governments not to regulate such that jobs are lost due to delocation. A direct interest in jobs by the government could be modeled by including the revenue from a tax t_L on labor in the objective function. Then the objective of the government is

$$(25) \qquad \max_{t_1} \quad w_1 = p(x_1 + x_2)x_1 - x_1 \cdot c(q_{L_1}, q_{E_1} + t_1, D_2 = 0) + t_1 \cdot E_1 + t_L \cdot q_{L_1} \cdot L_1 - DA_1(E_1)\,.$$

The monetary weight $t_L\ q_L$ could also be interpreted as a shadow price or political welfare evaluation given to an employed person in the industry.

Similarly, government in C2 chooses t_2 to maximize welfare subject to the condition that F2 stays in C2:

$$(26) \qquad \max_{t_2} \quad w_2 = p(x_1 + x_2)x_2 - x_2 \cdot c(q_{L_2}, q_{E_2} + t_2, D_1 = 0) + t_2 \cdot E_2 + t_L \cdot q_{L_2} \cdot L_2 - DA_2(E_2)$$

subject to

$$(27) \qquad \frac{d \ln c}{d\ D_1} + s_{F_2} = s_{L,2}\,\frac{d \ln q_L}{d\ D_1} + s_{E,2}\,\frac{d \ln q_E^0}{d\ D_1} + s_{t,2}\,\frac{d \ln t}{d\ D_1} + \frac{\partial \ln c}{\partial\ D_1} + s_{F_2} \geq 0\,.$$

For characterizing the optimum we consider the local Kuhn-Tucker conditions. The Lagrange function for C1 is:

$$L(t_1, l) = p_1(x_1(t_1,t_2), x_2(t_1,t_2), t_1) + t_1 \cdot E_1 + t_L \cdot q_{L_1} \cdot L_1 - DA_1(E_1) + l\left[\frac{d \ln c(t_1, t_2, D_2)}{d\ D_2} + s_{F_1}\right].$$

The conditions for an optimal solution $\hat{t}_1$, given t_2, are (it is $p_{x_1} = 0$, the FOC of the firm):

$$L_{t_1} = \frac{\partial p_1}{\partial x_2}\frac{\partial x_2}{\partial t_1} + t_1\frac{\partial E_1}{\partial t_1} + t_L \cdot q_{L_1} \cdot \frac{\partial L_1}{\partial t_1} - MDA_1 \cdot \frac{\partial E_1}{\partial t_1}\,.$$

(28) $$+ l \cdot \frac{\partial}{\partial t_1}\left[\frac{d \ln c(t_1 ; t_2 , D_2)}{d D_2} + s_{F_1} \right] \geq 0$$

It is $MDA_1 = \frac{d DA_1}{d E_1}$ the marginal damage due to emissions from burning fossil fuel E. In addition, restriction (23) must be satisfied, i.e

(29) $$L_l = \frac{d \ln c}{d D_2} + s_{F_1} \geq 0$$

Additional conditions are

(30) $$t_1 \cdot L_{t_1} = 0$$

(31) $$l \cdot L_l = 0 \,.$$

Let us first consider the case when $\hat{l} = 0$ is a solution. The inequality (23) need not be binding at the optimal tax $\hat{t}_1$; i.e., it is $\frac{d \ln c(\hat{t}_1 ; t_2)}{d D_2} + s_{F_1} > 0$ and the domestic location is not endangered at $\hat{t}_1$. The structure of the tax can be derived from the implicit reaction function (28):

(32) $$\hat{t}_1 = MDA_1 - \frac{\frac{\partial p_1}{\partial x_2}\frac{\partial x_2}{\partial t_1} + t_L \cdot q_{L_1} \cdot \frac{\partial L_1}{\partial t_1}}{\frac{\partial E_1}{\partial t_1}} \,.$$

This is the strategic tax of the Brander/Spencer type with $\hat{t}_1 < MDA_1$ because of $\frac{\partial p_1}{\partial x_2} < 0$, $\frac{\partial x_2}{\partial t_1} > 0$, $\frac{\partial L_1}{\partial t_1} < 0$ and $\frac{\partial E_1}{\partial t_1} < 0$. From differentiating (12') and (13') totally we know that $\frac{\partial x_1}{\partial t_1} < 0$ and $\frac{\partial x_2}{\partial t_1} > 0$; a higher tax is of disadvantage for F1. The sign of $\frac{\partial L_1}{\partial t_1}$ is ambiguous. It is

$$\frac{\partial L_1}{\partial t_1} = \frac{\partial L}{\partial x_1} \quad \frac{\partial x_1}{\partial t_1} + \frac{\partial L}{\partial q_{E_1}} .$$

If we assume that the negative output effect on labor demand from a higher tax dominates the positive substitution effect on labor (second term) from the tax induced increase in energy prices, then $\partial L_1 / \partial t_1$ is negative. Computable general equilibrium analyses in the context of the double dividend hypothesis have shown that the negative output effect is stronger than the positive substitution effect even if the tax revenue is used to reduce non-wage labor cost. Under our assumption of weak substitution between energy and labor, the strategic effect in (32) is enforced by the concern of the government that lost jobs imply less revenue from the labor tax.

If $\hat{l} > 0$, then (31) and (29) imply a tax rate $\hat{t}_1$ to prevent migration. Since marginal damage is high, the tax should be high but only such that the firm is indifferent between staying and relocating. Since $\hat{t}_1 > 0$ in (30), a system of two equations in t_1 and l has to be solved, namely (23) and (28) as equations. From (23) follows that the magnitude of the tax is such that the difference in the tax rates makes up for the advantage in the cost of production:

(33) $$-s_{t,1} \frac{t_2 - t_1}{t_1} = s_{L,1} \frac{d \ln q_L}{d D_2} + s_{E,1} \frac{d \ln q_E^0}{d D_2} + \frac{\partial \ln c_1}{\partial D_2} + s_{F_1} .$$

If we multiply (33) by $q_{E_1} + t_1$, we obtain

(34) $$s_{E\,t,1} (\hat{t}_1 - t_2) = \left(s_{L,1} \frac{d \ln q_L}{d D_2} + \frac{\partial \ln c}{\partial D_2} + s_{F_1} \right) \cdot (q_{E_1} + \hat{t}_1) + s_{E\,t,1} \frac{d q_E^0}{d D_2}$$

where $s_{E\,t,1} = \frac{(q_{E_1} + \hat{t}_1) \cdot E_1}{x_1 \cdot c_1}$ is the cost share of energy, including the tax. Because of our assumption of constant returns to scale, the cost shares are independent on output x_1. If we assume in addition that cost shares do not depend on prices, then (34) is linear in t_1 and t_2

(provided the productivity difference is a constant). If (34) is solved for $\hat{t}_1$ as a function of t_2, (28) can be used next to solve for l.

If we finally assume that marginal damage is also high in C2, implying in principle also a high tax t_2 such that F2 would relocate, we obtain the analogous case with $\hat{t}_2$ as a function of t_1, and a $\hat{l} > 0$. From (27), using $\frac{d\,t}{d\,D_1} = t_1 - t_2$, we obtain

(35) $$s_{E\,t,2}\,(\hat{t}_2 - t_1) = \left(s_{L,2}\,\frac{d \ln q_L}{d\,D_1} + \frac{\partial \ln c}{\partial\,D_1} + s_{F_2} \right) \cdot \left(q_{E_2} + \hat{t}_2 \right) + s_{E\,t,2}\,\frac{d\,q_E^0}{d\,D_1}$$

where $c(\cdot) = c(\,q_{L_2}, q_{E_2} + t_2, D_1 = 0)$. If cost shares and the rate $\frac{\partial \ln c}{\partial\,D_1}$ are constant, then $\hat{t}_2$ is a linear function of t_1 and it is $\frac{d\,\hat{t}_2}{d\,t_1} > 0$. The higher the energy tax in C1, the higher t_2 can be set as an upper limit to prevent relocation. If marginal damage is high in both countries such that both governments will set the tax rates to their upper limit, then the simultaneous system (34) and (35) has to be solved for $\hat{t}_1$ and $\hat{t}_2$. If cost shares and the rate of productivity are constant, there exists one obvious solution $\hat{t}_1 = -q_{E_1}$, $\hat{t}_2 = -q_{E_2}$ which implies $\hat{t}_1 - \hat{t}_2 = \frac{d\,q_E^0}{d\,D_2} = -\frac{d\,q_E^0}{d\,D_1}$. Energy should be subsidized such that its price is zero. This race to the bottom is, however, not linked to the “environmental surplus” in the objective function. A solution where damage is high and the government pays for the energy bill minimizes instead of maximizes welfare.[10] The welfare maximizing solution would obviously be the NIMBY case, i.e. both governments are not interested in having the firm in the country. To shut down production is the optimal solution. Therefore subsidizing energy will stop at the point where $w_i < 0$.

Let us summarize the features of our two-stage game. The governments know the Nash solutions of the game of the firms in quantities $x_1(t_1, t_2)$ and $x_2(t_1, t_2)$. They compete at the first stage in taxes to control the environmental externality by mitigating at the same time

[10] If the cost shares and the change in productivity depend on factor prices, then the simultaneous system (34) and (35) is non-linear in t_1 and t_2, and a solution might be not unique or does not exist.

the loss of market shares to foreign competitors and by preventing the relocation of its firms. We obtained two sets of taxes. If marginal damage does not require a tax which drives the firm out of the country, then governments set strategic taxes below marginal damage, the eco-dumping case. Solving the implicit reaction functions (32), $\hat{t}_1 = r_1(t_2)$, and the analogous function $\hat{t}_2 = r_2(t_1)$, a Nash equilibrium in tax rates can be derived. Our second case would require a very high tax due to high marginal damage. However, such a tax would induce the firm to relocate. Therefore, the government chooses an upper limit of the tax which makes the firm indifferent of staying or relocating. If the same situation prevails in the other country, the simultaneous solution of the two conditions (34) and (35) yields a "tax" program. Since the conditions do not depend on $x_i(t_1, t_2)$, an explicit solution can be calculated if cost shares and TFP are constant. The result is an extreme case of eco-dumping in terms of a total subsidization of energy. The competition for the location completely neglects welfare and minimizes the "environmental surplus". In a third case, t_1 is modest and F1 will stay in the country. Equation (32) is then the relevant implicit reaction function. But in C2 the tax t_2 is high and set at a level such that F2 is indifferent between staying or migrating. The response on t_1 is determined by (35). Solving these two implicit reaction functions for t_1 and t_2 yields an equilibrium, providing it exists and is unique.[11]

5. Some extensions

5.1 The impact of different standards on location decisions

We next assume that countries differ in terms of their standards of abating air pollution from the burning of fossil fuel. For that purpose we assume that regulation affects the user cost of energy by adding the cost of regulation to the price of energy. For firm 1 the user cost of energy is then

$$q_E(D_2) = q_E^0(D_2) + t_E(D_2) + ca(a(D_2)) \cdot a(D_2) \cdot e$$

[11] Our case with indifference, i.e. $\frac{d \ln c}{d\ D_2} = 0$, is characterized in the literature (e.g. Ulph (1997)) by a level of an emission tax at which it would pay the firm to shut down production. This $t_1 = T$ effectively acts as an upper limit on the tax rates.

where $a(D_2)$ is the degree of abatement and $ca(a(D_2))$ are the costs of abatement measures per unit of abated emission. They depend on the degree of abatement with $ca_a > 0$ and $ca_{aa} > 0$. The degree of abatement, *a*, represents the enforcement in pollution control. It is defined as the ratio of emission to be abated (e.g. SO_2) over the maximum SO_2 pollution, i.e. potential SO_2 emissions $(0 \le a \le 1)$. The coefficient *e* is an emission coefficient for SO_2 (e.g. from coal) and q_E^0 is the base price of the air polluting input. With $ca(a)$ monotone increasing in *a*, the user cost of energy increases over-proportional with an enforcement in environmental regulation. This implies on the input side an increasing share of "unproductive" material inputs to comply with regulation.

From $C_1 = C(x_1, q_L(D_2), q_E(D_2), D_2)$ we can again calculate the difference in costs if the firm in country 1 relocates:

$$\frac{d\,C}{d\,D_2} = L_1 \frac{d\,q_L}{d\,D_2} + E_1 \cdot \left(\frac{d\,q_E^0}{d\,D_2} + \frac{d\,t_E}{d\,D_2} + (ca_a \cdot a + ca)e \frac{d\,a}{d\,D_2} \right) + \frac{\partial\,C}{\partial\,D_2}.$$

Written in logarithmic changes, the firm 1 remains in country 1 if costs are higher after relocation:

$$\frac{d\ln C}{d\,D_2} = s_{L_1} \frac{d\ln q_L}{d\,D_2} + s_{E_1} \frac{d\ln q_E^0}{d\,D_2} + s_{t_1} \frac{d\ln t_E}{d\,D_2} + \frac{C_1^R}{C_1}\left[1 + e_{c\,a\,a}\right] \frac{d\ln a}{d\,D_2} + \frac{\partial \ln C}{\partial\,D_2} \ge 0 \qquad (36)$$

where $C_1^R = ca \cdot a \cdot e \cdot E_1$ are the costs of regulation and $e_{c\,a\,a} > 0$ is the elasticity of abatement costs with respect to the degree *a*. The new aspect in (36) is the impact of differences in the degree of abatement on the location decision. If the productivity aspect (last term) has offset the first three cost components and the firm was nearly indifferent in its location choice, then the prospect of a lower standard *a* in country 2 can reverse the sign in (36), which leads to relocation. This effect is the stronger the higher the cost of regulation and the more convex the abatement cost function is. The Nash equilibrium of the quantity game of the firms now depends on the degrees of regulation, $x_i(a_1, a_2)$. The objective of the government is to maximizes welfare

$$\max_{a_1} \quad p(x_1 + x_2)x_1 - x_1 \cdot c(q_{L_1}, q_{E_1}) + t_L \cdot q_{L_1} \cdot L_1 - DA(E_1)$$

subject to (36).

The Lagrange function for C1 is

$$L(a_1, l) = p_1(x_1(a_1, a_2), x_2(a_1, a_2), a_1) + t_L \cdot q_{L_1} \cdot L_1(\cdot) - DA_1(E_1(\cdot)) + l \left[\frac{d \ln C}{d D_2} \right]$$

where $(\cdot)$ includes the arguments of the cost function, i.e. $x_1(a_1, a_2), q_L$ and $q_E(a_1)$. The conditions for an optimal degree of abatement $\hat{a}_1$, given a_2, are:

$$(37) \qquad L_{a_1} = \frac{\partial p_1}{\partial x_2}\frac{\partial x_2}{\partial a_1} - E_1 \frac{\partial q_E}{\partial a_1} + t_L \cdot q_{L_1} \frac{\partial L_1}{\partial a_1} - MAD_1 \frac{\partial E}{\partial a_1} + l \frac{\partial}{\partial a_1}\left[\frac{d \ln C}{d D_2} \right] \geq 0 .$$

Additional conditions, besides (36), are

$$(38) \qquad a_1 \cdot L_{a_1} = 0 \qquad\qquad l \cdot L_l = 0 .$$

We first consider the case $\hat{l} = 0$, that is marginal damage is not high enough and foreign regulation (a_2) is not lax enough so that the domestic location is not endangered at $\hat{a}_1$. As $\partial q_E / \partial a_1 = (ca' \cdot a_1 + ca)\, e$, we obtain from (37) an implicit reaction function for a_1, expressed in terms of marginal abatement costs:[12]

[12] For more detail see the Appendix.

(39) $$ca'(\hat{a}_1)\cdot\hat{a}_1 + ca(\hat{a}_1) = \frac{MDA_1\left|\frac{\partial E_1}{\partial a_1}\right| - t_L\cdot q_{L_1}\left|\frac{\partial L_1}{\partial a_1}\right| - \left|\frac{\partial p_1}{\partial x_2}\frac{\partial x_2}{\partial a_1}\right|}{e\cdot E_1}.$$

Marginal abatement cost and therefore a_1 will increase with marginal damage, but the environmentally justified degree a_1 will be reduced because a stricter regulation leads to less jobs (second term in (39)) and lower profits due to the loss in market shares (third term).

If $\hat{l} > 0$, the unknown degree of abatement a_1 can be calculated from (36), stated as an equality. The “best response” $\hat{a}_1 = a_1(a_2)$ is a less strict regulation in spite of high marginal damage. Although regulation was laxer anyway from an environmental point of view because of concerns about jobs and competitiveness, it is even laxer now because of concern about the relocation. Similarly as in the tax case, if the other country is also concerned about relocation of its industry, there might be a race to the bottom in terms of low degrees of abatement.

5.2 A Duopoly with Multi-Location Options

We still consider two firms which produce a homogeneous good for the world market with $p = p(x_1 + x_2)$ as the inverse demand function. They can, however, choose among n locations where to produce their output level $x_i,\quad i = 1, 2$. In that case, firm 1 maximizes

$$\max_{x_1}\quad p_1 = p(x_1 + x_2)x_1 - C(x_1, q_L(D_{-1}), q_E^0(D_{-1}) + t_1(D_{-1}), D_{-1}) - \sum_{j\neq 1}^{n} D_j\cdot F_{1,j}$$

where $D_{-1} := (D_2, D_3, ..., D_n)$. Similarly, firm 2 maximizes

$$\max_{x_2}\quad p_2 = p(x_1 + x_2)x_2 - C(x_2, q_L(D_{-2}), q_E^0(D_{-2}) + t_2(D_{-2}), D_{-2}) - \sum_{j\neq 2}^{n} D_j\cdot F_{2,j}$$

where $D_{-2} := (D_1, D_3, ..., D_n)$. The firms can produce at any location; if they produce at home, then D_{-1} and D_{-2} are zero-vectors. If they produce at location i_0, then $D_{i_0} = 1$ and $D_i = 0$ for $i \neq i_0$. Fixed costs $F_{i,j}$ differ among locations because of differences in distance, prices for land or financial conditions. The two FOC are (i = 1, 2):

$$MR_i(x_1, x_2) = c(q_L(D_{-i}), q_E^0(D_{-i}) + t_i(D_{-i}), D_{-i})$$

and the equilibrium output levels can be written as $x_i(t_1(D_{-1}), t_2(D_{-2}))$. Given the differences in factor prices, government i can influence profit, market share and location decision by choosing t_i, knowing the difference in regional tax rates, i.e. $t_i(D_{-i}) = t_i + \sum_{j \neq i} \Delta t_j \cdot D_j$. Similar to (14), the non-migration condition is:

$$(40) \qquad \frac{d}{d\,D_j}\left(c(q_L(D_{-i}), q_E(D_{-i}), D_{-i})\right) + \frac{F_{i,j}}{x_i} \geq 0 .$$

Since we consider a situation where firm i produces at location i before the two government consider to raise taxes, the inequality in (40) holds for all j. The margin for a tax increase is given by the minimum of the cost advantages to all regions. Let j_1 be the region where the cost advantage is smallest, i.e. the likelihood for relocation is highest. The objective of government 1 is now:

$$(41) \qquad \max_{t_1} \quad w_1 = p(x_1 + x_2) - x_1 \cdot c(q_{L_1}, q_{E_1} + t_1) + t_1 \cdot E_1 + t_L \cdot q_{L_1} \cdot L_1 - DA_1(E_1)$$

subject to

$$(42) \qquad \frac{d \ln c}{d\,D_{j_1}} + s_{F_1,j_1} = s_{L,1}\frac{d \ln q_L}{d\,D_{j_1}} + s_{E,1}\frac{d \ln q_E^0}{d\,D_{j_1}} + s_{t,1}\frac{d \ln t}{d\,D_{j_1}} + \frac{\partial \ln c}{\partial\,D_{j_1}} + s_{F_1,j_1} \geq 0 .$$

In an analogous way, region j_2 is the region where the cost advantage of country 2 is smallest. Therefore, D_1 in (27) has to be replaced by D_{j_2}.

We conclude that the implicit reaction functions for the tax rates do not change if the relocation restriction are not binding. If one restriction is binding, e.g. (42), then $t_1 = t(t_{j_1})$ follows from (42). The tax rate is independent on t_2 if j_1 is not country 2. Environmental policy in country j_1 where the competitor is not located at determines the tax rate. This tax rate influences $x_i(t_1, t_2)$, but strategic tax rate $\hat{t}_2$ is not strategic any more because $\hat{t}_2$ has no impact on the environmental policy of country 1.

5.3 ECO-Dumping to Attract the Foreign Firm

If countries differ in marginal damage, the country with the low marginal damage might set a low emission tax to make it profitable for the foreign firm to relocate. The government of country 1 could choose a level of t_1 such that

(43) $$\frac{d\, c(\cdot, D_2)}{d\, D_2} + F_1 \geq 0 \quad \text{as well as} \quad \frac{d\, c(\cdot, D_1)}{d\, D_1} + F_2 < 0,$$

i.e., F1 stays within the country and F2 decides to relocate, given t_2 in country 2. If t_1 is such that (43) holds, the market structure is a symmetric duopol producing in C1. The inequality conditions are (see **(23)** and (27)):

(44) $$\frac{d \ln c}{d\, D_2} + s_{F_1} = s_{L,1} \frac{d \ln q_L}{d\, D_2} + s_{E,1} \frac{d \ln q_E^0}{d\, D_2} + s_{t,1} \frac{d \ln t}{d\, D_2} + \frac{\partial \ln c_1}{\partial\, D_2} + s_{F_1} \geq 0$$

and

(45) $$\frac{d \ln c}{d\, D_1} + s_{F_2} = s_{L,2} \frac{d \ln q_L}{d\, D_1} + s_{E,2} \frac{d \ln q_E^0}{d\, D_1} + s_{t,2} \frac{d \ln t}{d\, D_1} + \frac{\partial \ln c}{\partial\, D_1} + s_{F_2} \leq 0,$$

where we have replaced for mathematical reasons (Kuhn-Tucker) the strict inequality condition $\frac{d\,c}{d\,D_1} + F_2 < 0$ by $\leqq$.[13] If the inequality conditions (44) and (45) are satisfied, both firms produce in C1 and the welfare maximizing problem of its government is:

(46) $\max_{t_1} \quad p\left[2x_1(t_1)\right]2\cdot x_1(t_1) - 2x_1\, c(\cdot) + t_1\cdot 2E_1 + 2t_L\cdot q_{L_1}\cdot L_1 - DA_1\,(2E_1)$

subject to (44) and (45). The Lagrange function for the Kuhn-Tucker conditions is:

$$L(t_1, l, m) = 2p_1(x_1(t_1), t_1) + 2t_1\cdot E_1 + 2t_L\cdot q_{L_1}\cdot L_1 - DA_1(2E_1) + l\left[(44)\right] - m\left[(45)\right] .$$

The condition for an optimal tax t_1, given t_2 in (44) and (45), is:

(47) $L_{t_1} = 2\cdot t_1 \frac{\partial E_1}{\partial t_1} + 2t_L\cdot q_{L_1}\frac{\partial L_1}{\partial t_1} - MDA_1\cdot\left(2\cdot\frac{\partial E_1}{\partial t_1}\right) + l\,\frac{\partial}{\partial t_1}\left[(43)\right] - m\frac{\partial}{\partial t_1}\left[(44)\right] \geq 0$

(48) $L_l = \left[(44)\right] \geq 0$

(49) $L_m = -\left[(45)\right] \geq 0$

and

(50) $t_1\cdot L_{t_1} = 0 \quad , \qquad l\cdot L_l = 0 \quad , \qquad m\cdot L_m = 0 .$

There are four possible solutions:

The case $l = 0, m = 0$ implies that marginal damage is (seen to be) low in C1. The tax t_1 is low and both firms will produce in C1, given t_2. The tax follows from (47), i.e., MDA is adjusted downwards by the job creation aspect:

[13] The indifference situation as a reason to relocate could be justified, if at all, by the expectation of F2 that the government of C1 is highly interested in job creation for its labor force and will provide the environment at low costs also in the future.

$$\hat{t}_1 = MDA_1 - \frac{t_L \cdot q_{L_1} \dfrac{\partial L_1}{\partial t_1}}{\dfrac{\partial E_1}{\partial t_1}}$$

If we had dropped this aspect, $\hat{t}_1$ would have been a first best Pigou tax. The intuition is that the tax corrects the environmental externality, and other externalities like relocation of domestic firms or attracting foreign firms require no additional policy aspect. Since both firms produce in one country, there is no need for additional eco-dumping in order to gain market shares on a third market.[14]

In case of $l \neq 0$, $m = 0$, marginal damage is high in C1 and so is $\hat{t}_1$. The tax follows from (34) which is equivalent to (44) as equation and makes F1 indifferent with respect to its location decision. F2 considers $\hat{t}_1$ as low compared to t_2 and relocates.

If $l = 0, m \neq 0$, F1 considers $\hat{t}_1$ as low and will not migrate. If $\hat{t}_1$ is compared to t_2, however, F2 has to be attracted by a lower tax than $\hat{t}_1$ which follows from (45) as indifference condition, i.e. from its equivalent condition (35).[15]

Finally, if $l \neq 0$, $m \neq 0$, $\hat{t}_1$ had to solve simultaneously (44) and (45) as equalities. Environmental damage matters in C1 but not so much in C2. The upper limit for t_1 is to achieve indifference for the domestic firm ($\hat{t}_1$ from (44), i.e. from (34)), and disregard the idea to attract the foreign firm.

It is obvious that a tax competition between the two governments to attract both firms would imply the indifferent solution. The inequalities, equivalent to (43), if the government in C2 maximizes welfare, are

(51) $$\frac{d\, c(\cdot, D_1)}{d\, D_1} + F_2 \geq 0 \quad , \qquad \frac{d\, c(\cdot, D_2)}{d\, D_2} + F_1 < 0$$

[14] Note that there is no tax game between the governments because the government of C2 is passive and sticks to t_2.

[15] Since indifference is not enough to attract F2 if it has already set up a plant in C2, $\hat{t}_1$ has to be somewhat below the indifference level.

which are just the opposite inequalities compared to (43). The solution of the tax game implies indifference of both firms, i.e. $\hat{t}_1$ and $\hat{t}_2$ have to solve the equalities (44) and (45). These equalities are the same as discussed in section 4 when we solved (34) and (35) for a full subsidizing of energy. This was not an equilibrium and implied that each firm stays in its country or should be shut down. This result is obvious because if one government succeeds in attracting both firms, welfare in the other country would be zero. Such an outcome could be optimal for both countries only when environmental damage from production at one of the locations is so high that welfare would be negative. Therefore, if both governments want to attract the firms and welfare remains positive, they end up in paying for the energy bill. If we restrict welfare of being non-negative, the size of the subsidies will be such that welfare becomes zero.

6. Summary and Conclusion

Whether a firm wishes to relocate or to invest abroad depends, among other things, on the framework which is provided by the government.[16] To a certain extent, governments are able to keep mobile factors of production at home if those factors can be attracted from abroad. The purpose of this paper has been to outline an analytical framework which captures the full scope of locational competition. Cost differences, one of the reason for migration of firms, result from differences in factor prices, including differences in the tax system (e.g. capital or non-wage labor cost), in human capital, in R&D expenditure, in infrastructure services, in public goods and, finally, in total factor productivity. If cost differences are small, locational competition controls excessive government power. In that case, a country with strict regulation and high tax rates will suffer from its politics. We have modeled locational competition by assuming that governments have a vital interest to keep mobile factors of production at home. We represent this aspect by restricting the level of the environmental instrument such that it will exhaust at the utmost the cost difference to a competing country. If cost differences are significant, then threats to relocate are not credible, i.e. there is no binding restriction for the cost-benefit calculus of a national environmental policy. In that case the government will tax according to marginal damage, but adjusts this tax rate downwards to shift profit from the foreign to its domestic firm in addition to maintaining labor income of its

[16] See Siebert (1999) for aspects on locational competition.

residents under the lower economic activity. If small cost differences do not allow taxation according to marginal damage, then locational competition restricts the scope of action of the government and a relocation indifference restriction is used to exhaust the possibility of at least a small environmental tax. In an extreme case when both countries are confronted with relocation, even a subsidy of energy is a thinkable means to keep the firms from migration. Our approach to locational competition was based on the consideration that governments are not interested in inducing mobile factors to leave the country. Through this assumption we circumvented the fact that physical capital is completely mobile ex ante when capital is not yet embodied in machinery, but it is almost immobile ex post. Our plan for future research is to model mobility of new capital, i.e. investment, while running the domestic plant without reinvesting in machinery. This aspect implies increasing returns to scale of the new, but small, foreign plant and requires a more complex analysis. However, before one starts with such an approach, empirical investigations should indicate that firms really set up plants in foreign countries because of a strict environmental regulation at home.

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Appendix

Proof of (38):

From (37) follows:

$$ca' \cdot a + ca = \frac{\left[-MDA_1 \frac{\partial E_1}{\partial a_1} + t_L \cdot q_L \frac{\partial L_1}{\partial a_1} + \frac{\partial p_1}{\partial x_2} \frac{\partial x_2}{\partial a_1}\right]}{e \cdot E_1}.$$

It is $\frac{\partial E_1}{\partial a_1} = \underset{(+)}{\frac{\partial E_1}{\partial x_1}} \underset{(-)}{\frac{\partial x_1}{\partial a_1}} + \underset{(-)}{\frac{\partial E_1}{\partial q_E}} \underset{(+)}{\frac{\partial q_E}{\partial a_1}} < 0$

And $\frac{\partial L_1}{\partial a_1} = \underset{(+)}{\frac{\partial L_1}{\partial x_1}} \underset{(-)}{\frac{\partial x_1}{\partial a_1}} + \underset{(+)}{\frac{\partial L_1}{\partial q_{E_1}}} \underset{(+)}{\frac{\partial q_{E_1}}{\partial a_1}} < 0$

if we assume again that the negative output effect on labor dominates the positive substitution effect on labor from the higher cost of energy. Finally, it is $\frac{\partial p_1}{\partial x_2} \frac{\partial x_2}{\partial a_1} < 0$ because the competitor's output increases with stricter regulation in country 1 which depresses p_1.