Optimal Taxation, Global Externalities and Labor Mobility*

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Abstract

This paper addresses transboundary environmental problems in the context of an optimal tax problem, when part of the labor force is mobile across countries. The policy instruments include both commodity taxation and nonlinear income taxation. We show how the tax policy in a noncooperative equilibrium differs from that corresponding to a cooperative equilibrium. The results also indicate how a 'global policy maker' must act in order to make the national policy makers replicate the cooperative equilibrium.

Keywords: Transboundary externalities, fiscal federalism, optimal taxation

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1 Introduction

Many environmental problems are transboundary in the sense that emissions caused by the production and/or consumption in one particular country affect the wellbeing of consumers in other countries. The emissions of CO_2 give rise to such transboundary environmental problems, since global warming may influence the living conditions of mankind in all countries irrespective of where the sources of emissions are located. Similarly, emissions of sulphur are spread by the wind across country boarders, meaning that the emissions undertaken by a particular country will cause environmental damage in other countries as well. This type of environmental problem has received a lot of attention in the literature[1].

The appropriate design of 'environmental taxation' (and other corrective policies) to internalize transboundary externalities from environmental damage typically depends on the whole set of objectives, instruments and restrictions facing policy makers. The methods to achieve distributional objectives and the potential mobility of tax bases across countries are particularly important in this context. For instance, if policy makers cannot observe the ability (or productivity) of different individuals, distributional objectives may necessitate the use of distortionary taxation. This means, in turn, that environmentally motivated taxes become part of a distortionary tax system. Similarly, if the labor force is mobile, it is reasonable to assume that differences in environmental and other policies between countries will induce migration. Since the size and composition of the labor force are likely to affect both the 'environmental quality' and the tax base, one may generally expect the incentives related to migration to influence public policy. Policy implications of labor mobility are thoroughly addressed in the literature on

[1] Previous research includes Mäler (1989), Barrett (1990, 1994), Carraro and Siniscalco (1993), Cesar (1994), Tahvonen (1994, 1995), Mäler and de Zeeuw (1995), Aronsson and Löfgren (2000) and Aronsson et al. (2000).

fiscal federalism[2], although commonly neglected in the context of environmental policy[3].

In this paper, we address transboundary environmental problems in the context of an optimal tax problem, where (part of) the labor force is mobile across countries. The analysis is based on a multi-country model, where the consumers in each country differ with respect to ability, and the (national) tax instruments include commodity taxation and nonlinear income taxation. The paper contributes to the existing literature in at least two ways. First, it relates the taxation of global externalities to other aspects of fiscal policy and recognizes that the tax revenues are raised by distortionary taxation. Previous studies on transboundary environmental problems typically disregard distributional objectives and tax revenue requirements, which means that the first best resource allocation can be achieved by Pigouvian taxation on a global level. It is, therefore, important to extend the study of transboundary environmental problems to situations, where the fiscal policy also aims at fulfilling distributional objectives, and the tax revenues are raised by distortionary taxation. Second, previous studies on environmental policy in economies with distributional objectives and/or distortionary taxation are based on 'one-country' model economies[4], in which there are no room for transboundary environmental problems. Seen from this point of view, the paper extends the literature on taxation of environmental externalities in the presence of other tax distortions.

Each individual country will be described by a variant of the two-type model used by Pirttilä and Tuomala (1997). Their basic model is here extended by assuming that the environmental damage caused by one particular

[2] See e.g. Wildasin (1991) and Boadway et al. (1998).

[3] Sandmo and Wildasin (1999) and Hoel and Shapiro (2000) are notable exceptions..

[4] See e.g. Bovenberg and de Mooij (1994), Bovenberg and van der Ploeg (1994), Pirttilä and Tuomala (1997) and Aronsson (1999). See also Golder (1995) for a literature review on the 'double dividend' issue.

country will affect other countries as well, and by allowing for mobility among high ability types. One purpose of the paper is to compare the (conditionally optimal) second best policy in a noncooperative equilibrium with that of a cooperative equilibrium. Since the environmental damage is assumed to originate from the aggregate consumption of a specific commodity - to be called a 'dirty' good - a particular concern will be to study what factors determine the optimal choice of commodity taxation. We show that the mobility incentives characterizing the high ability types may influence the optimal commodity tax (as well as the effective marginal tax rates) via two distinct channels in the noncooperative regime. First, to avoid a loss of tax base, the national government has an incentive to choose a lower commodity tax than would be chosen in the absence of labor mobility. Second, since out-migration reduces the aggregate consumption of the dirty good, the national government can reduce the domestically created environmental damage by stimulating out-migration. Since each national government treats the policy variables of other countries as exogenous, this provides an incentive to choose a higher commodity tax than in the absence of mobility. However, irrespective of which of these two effects is dominating, part of the externality will remain uninternalized in the noncooperative equilibrium.

In the cooperative regime, on the other hand, all externalities are internalized on a global level, which means that the optimal commodity tax facing a country will reflect all welfare effects (both domestically and abroad) caused by that particular country's emissions. The fiscal policy implicit in the cooperative equilibrium suggests that each country's commodity tax does not only depend on the sum of all countries' willingness to pay to avoid its contribution to the externality (as it would in the absence of distortionary taxation). It also depends on the restrictions underlying the distributional policy in all countries. This has in interesting interpretation: the desire to avoid mimicking in a particular country influences the commodity taxes in other countries as well.

Another purpose is to study whether a 'federal' government can implement the cooperative equilibrium is a decentralized setting, where each individual country chooses its policy in isolation by acting in accordance with the noncooperative model. We show that it is, in principle, possible to implement the cooperative equilibrium in a decentralized framework, even if this requires that the federal government has access to some 'nonstandard' policy instrument. To take the issue of cooperation a bit further, the final part of the paper addresses the welfare consequences of an agreement between the countries to slightly change their commodity taxes, when the prereform situation is given by the noncooperative equilibrium. The latter makes it possible to identify conditions under which the optimal direction of such a tax reform is to increase or decrease the commodity taxes. This is interesting both as a 'practical' alternative to full cooperation over the environmental policy and by providing a framework for studying green tax reform in a global economy with preexisting tax distortions.

There only exist a couple of earlier studies concerning transboundary externalities and labor mobility. Sandmo and Wildasin (1999) focus on the optimal environmental and immigration policies from the point of view of a single jurisdiction, which treats the actions taken in other jurisdictions as exogenous. It is shown how the 'conditionally optimal' environmental tax (i.e. whether or not this tax can be calculated by using a standard Pigouvian formula) depends on what instrument is being used to control immigration. Hoel and Shapiro (2000) also address transboundary environmental problems under a mobile population. Their most important result is that a noncooperative equilibrium with free mobility across jurisdictions will, under certain conditions, imply a pareto efficient allocation of the resources. In this case, therefore, there is no reason to have an international (or interjurisdictional) coordination of the environmental policy. Our paper differs from the studies by Sandmo and Wildasin (1999) and Hoel and Shapiro (2000) both in terms of focus and use of policy instruments.

The model is formally described in Section 2. Section 3 addresses the tax and expenditure policies implicit in a cooperative equilibrium. The cooperative equilibrium is based on the assumption of a benthamite 'global planner', who chooses tax and expenditure policies for all countries involved. Section 4 concerns optimal tax and expenditure policies, when the countries form their policies in isolation. In Section 5, we examine a global tax/subsidy scheme, which will be designed to give the individual countries incentives to choose the cooperative equilibrium. Section 6 addresses the welfare effects of introducing an additional, and cooperatively chosen, commodity tax in the noncooperative equilibrium. Section 7 concludes.

2 The Model

We begin by a presentation of the model. With the model at our disposal, we shall briefly characterize the equilibria resulting from full cooperation and a noncooperative Nash-game between the countries, respectively. From the point of view of the analysis to be carried out below, the number of countries is not important (as long as there is more than one country). We shall, therefore, simplify by considering a two-country economy. The two countries are identical in all important respects.

Each country consists of two types of individuals; type-1 individuals with lower ability and type-2 individuals with higher ability, so $w_j^2 > w_j^1$, where w_j^i is the gross wage rate facing an individual of type i in country j. Individuals earn labor income, $Y_j^i = w_j^i l_j^i$, with l_j^i denoting labor supply. Income is taxed according to a nonlinear schedule, and each individual allocates his/her post-tax income, B_j^i, between a 'clean' consumption good, c_j^i, and a 'dirty' consumption good, x_j^i. The aggregate consumption of dirty goods creates an externality, E_j (see below), which spills over to the other country. Each individual behaves as if the aggregate consumption of dirty goods is exogenous.

An individual of type i in country j chooses consumption and labor supply so as to maximize

$$u_j^i = u(c_j^i, x_j^i, l_j^i, g_j, E_j, E_k) \tag{1}$$

for $j = 1, 2$, and $k \neq j$, where g_j denotes consumption of a public good. We normalize the price of c to one and denote the price of x by q. The budget constraint can then be written as

$$c_j^i + q_j x_j^i = Y_j^i - T_j(Y_j^i) \tag{2}$$

where $T_j(\cdot)$ is an income tax function. The price of the dirty consumption good is defined as $q_j = p_j + t_j$, where p_j is the producer price and t_j a unit tax.

Following Christiansen (1984) we start by solving the utility maximization problem conditional on the labor supply. By choosing c_j^i and x_j^i to maximize the utility function subject to equation (2), while using the short notation $B_j^i = Y_j^i - T_j(Y_j^i)$, we can write the conditional indirect utility function as

$$v_j^i = v_j^i(q_j, B_j^i, Y_j^i, g_j, E_j, E_k) \tag{3}$$

for $k \neq j$, in which we have used $l_j^i = Y_j^i / w_j^i$ and then suppressed the wage rate. Note that, even if the two ability types have identical preferences, the functions $v_j^1(\cdot)$ and $v_j^2(\cdot)$ will differ because the wage rates differ across ability types. The optimal labor supply will obey the condition

$$\frac{\partial v_j^i}{\partial B_j^i}(1 - T_j'(Y_j^i)) + \frac{\partial v_j^i}{\partial Y_j^i} = 0 \tag{4}$$

where $T_j^{'}(Y_j^i)$ is the marginal income tax rate corresponding to income level Y_j^i. We shall introduce the agent monotonicity condition by assuming that $-[\partial v_j^i/\partial Y_j^i]/[\partial v_j^i/\partial B_j^i]$ decreases with w_j^i.

As we mentioned above, the externalities are generated by the aggregate consumption of dirty goods, i.e.

$$E_j = \sum_i x_j^i \tag{5}$$

We assume that externalities generated domestically as well as abroad are negative, meaning that $\partial v_j^i/\partial E_j < 0$ and $\partial v_j^i/\partial E_k < 0$.

The high ability types are mobile across countries, whereas the low ability types are not. To determine migration, we use the 'attachment to home' idea developed by Mansoorian and Myers (1997), which will here be interpreted as if individuals have a psychological attachment to their native country. This disutility of migration varies between individuals of the high ability type. By ranking individuals in terms of increasing order of disutility of migration, we denote by $d(M)$ the disutility of the M:the individual of type 2 if he/she decides to migrate. We assume $d^{'}(M) > 0$, $d(0) = 0$ and $-d(M) = d(-M)$. This enables us to determine the number of individuals migrating out of country j (and into the other country) by solving[5]

$$v_j^2(q_j, B_j^2, Y_j^2, g_j, E_j, E_k) = v_k^2(q_k, B_k^2, Y_k^2, g_k, E_k, E_j) - d(M_j) \tag{6}$$

for $j = 1, 2$, and $k \neq j$. Note that $M_j(\cdot)$ can be either positive or negative. The migration out of country j, $M_j(\cdot)$, decreases with B_j^2, g_j, q_k and Y_k^2, increases with q_j, Y_j^2, B_k^2 and g_k, whereas the effects of the externality terms, E_j and E_k, are in general ambiguous. If the domestically created externality gives rise to more (less) disutility at the margin than the externality created

[5] Boadway et al. (1998) use a similar model to determine migration between states in an economic federation.

by the other country, then $\partial M_j(\cdot)/\partial E_j > 0$ (< 0) and $\partial M_j(\cdot)/\partial E_k < 0$ (> 0) for $k \neq j$.

3 A Cooperative Equilibrium

In a cooperative equilibrium, all externalities are internalized on a global level. Suppose that the resource allocation is decided upon by a 'global planner', who is acting as a benthamite welfare-maximizer. The planner will choose tax and expenditure policies to maximize the sum of the country specific objective functions subject to all restrictions characterizing the two economies. Since the two countries are identical, the cooperative equilibrium will be a symmetric equilibrium with no migration. This is recognized by the planner and we can, therefore, delete any references to migration. The policy we will study in this section can be regarded to be the restricted first best policy on a global level. That is, it is a pareto efficient policy, given the technological and informational constraints.

The objective of the global planner is to maximize the sum of the utilities of the type 1 individuals subject to constraints. The first constraint is that the utility of the high ability type does not fall short of a certain predetermined level;

$$v_j^2(q_j, B_j^2, Y_j^2, g_j, E_j, E_k) - \bar{v}^2 \geq 0 \tag{7}$$

Second, for each country there is a self selection constraint, which rules out that the high ability type increases his/her utility by mimicking the low ability type;

$$v_j^2(q_j, B_j^2, Y_j^2, g_j, E_j, E_k) - v_j^2(q_j, B_j^1, Y_j^1, g_j, E_j, E_k) \geq 0 \tag{8}$$

To simplify the notations as much as possible, we normalize the population in each country such that there is one low ability type and one high ability type.

We also assume that the budget within each country has to be balanced. The budget constraint for country j facing the global planner can then be written as

$$\sum_i [Y_j^i - c_j^i - p_j x_j^i] - r_j g_j \geq 0 \tag{9}$$

where $c_j^i = c_j^i(q_j, B_j^i, Y_j^i, g_j, E_j, E_k)$, $x_j^i = x_j^i(q_j, B_j^i, Y_j^i, g_j, E_j, E_k)$ and r_j is the price of public goods.

The Lagrangean corresponding to the global planner's optimization problem is written as

$$\begin{aligned} L &= \sum_j \{v_j^1(\cdot) + \delta_j[v_j^2(\cdot) - \bar{v}^2] + \lambda_j[v_j^2(\cdot) - \hat{v}_j^2(\cdot)] \\ &\quad + \gamma_j[\sum_i (Y_j^i - c_j^i - p_j x_j^i) - r_j g_j] + \mu_j[E_j - \sum_i x_j^i]\} \end{aligned}$$

where $\hat{v}_j^2(\cdot) = v_j^2(q_j, B_j^1, Y_j^1, g_j, E_j, E_k)$. The optimal tax and expenditure policies can be derived by maximizing the Lagrangean with respect to Y_j^1, B_j^1, Y_j^2, B_j^2, g_j, q_j and E_j. Since the externality is modelled in terms of a separate restriction in the Lagrangean, we treat E_j as a decision variable. This procedure will provide a shadow price of the externality, which is useful in the analysis of optimal tax rules below. In addition to equations (5), (7), (8) and (9), the necessary conditions are

$$\frac{\partial v_j^1}{\partial Y_j^1} - \lambda_j \frac{\partial \hat{v}_j^2}{\partial Y_j^1} + \gamma_j[1 - \frac{\partial c_j^1}{\partial Y_j^1} - p_j \frac{\partial x_j^1}{\partial Y_j^1}] - \mu_j \frac{\partial x_j^1}{\partial Y_j^1} = 0 \tag{10}$$

$$\frac{\partial v_j^1}{\partial B_j^1} - \lambda_j \frac{\partial \hat{v}_j^2}{\partial B_j^1} - \gamma_j[\frac{\partial c_j^1}{\partial B_j^1} + p_j \frac{\partial x_j^1}{\partial B_j^1}] - \mu_j \frac{\partial x_j^1}{\partial B_j^1} = 0 \tag{11}$$

$$(\delta_j + \lambda_j)\frac{\partial v_j^2}{\partial Y_j^2} + \gamma_j[1 - \frac{\partial c_j^2}{\partial Y_j^2} - p_j \frac{\partial x_j^2}{\partial Y_j^2}] - \mu_j \frac{\partial x_j^2}{\partial Y_j^2} = 0 \tag{12}$$

$$(\delta_j + \lambda_j)\frac{\partial v_j^2}{\partial B_j^2} - \gamma_j[\frac{\partial c_j^2}{\partial B_j^2} + p_j \frac{\partial x_j^2}{\partial B_j^2}] - \mu_j \frac{\partial x_j^2}{\partial B_j^2} = 0 \tag{13}$$

$$\frac{\partial v_j^1}{\partial g_j}+(\delta_j+\lambda_j)\frac{\partial v_j^2}{\partial g_j}-\lambda_j\frac{\partial \hat{v}_j^2}{\partial g_j}-\gamma_j[\sum_i\frac{\partial c_j^i}{\partial g_j}+p_j\sum_i\frac{\partial x_j^i}{\partial g_j}+r_j]-\mu_j\sum_i\frac{\partial x_j^i}{\partial g_j}=0 \quad (14)$$

$$\frac{\partial v_j^1}{\partial q_j}+(\delta_j+\lambda_j)\frac{\partial v_j^2}{\partial q_j}-\lambda_j\frac{\partial \hat{v}_j^2}{\partial q_j}-\gamma_j[\sum_i\frac{\partial c_j^i}{\partial q_j}+p_j\sum_i\frac{\partial x_j^i}{\partial q_j}]-\mu_j\sum_i\frac{\partial x_j^i}{\partial q_j}=0 \quad (15)$$

$$\sum_k\{\frac{\partial v_k^1}{\partial E_j}+(\delta_k+\lambda_k)\frac{\partial v_k^2}{\partial E_j}-\lambda_k\frac{\partial \hat{v}_k^2}{\partial E_j}-\gamma_k[\sum_i\frac{\partial c_k^i}{\partial E_j}+p_k\sum_i\frac{\partial x_k^i}{\partial E_j}]-\mu_k\sum_i\frac{\partial x_k^i}{\partial E_j}\}+\mu_j=0 \quad (16)$$

where $j = 1, 2$. As is standard in the optimal tax literature, the optimization problem is not necessarily well behaved. To be able to compare our results with those of Pirtillä and Tuomala (1997), we assume that a unique equilibrium exists in which the shadow prices corresponding to the self-selection constraint and the government's budget constraint are strictly positive, i.e. $\lambda_j > 0$ and $\gamma_j > 0$ at the equilibrium. Since the two countries are identical by assumption, this equilibrium will be symmetric in the sense that the planner chooses identical policies for the two countries. We therefore concentrate the analysis to the representative country, which will be indexed by "j". The country specific index makes it easy to distinguish between domestically generated externalities and externalities generated by the 'foreign' country.

3.1 Shadow price of externalities

In the context of a 'one-country' economy, Pirttilä and Tuomala (1997) have shown that the shadow price of the externality over the shadow price of the government's resource constraint plays an important role in the context of policy rules. To derive this 'normalized' shadow price for the economy set out here we define $\Omega_{j,k}^i = -[\partial v_k^i/\partial E_j][\partial v_k^i/\partial B_k^i]$ to measure the marginal willingness to pay by a type i in country k to avoid the externality created by country j. In addition, let us denote the Hicksian demands for clean and dirty consumption goods by $\tilde{c}_j^i$ and $\tilde{x}_j^i$, respectively. We shall also make use of the following Slutsky-type relationships;

$$\begin{aligned} \frac{\partial c_j^i}{\partial E_j} &= \frac{\partial \tilde{c}_j^i}{\partial E_j} - \Omega_{j,j}^i \frac{\partial c_j^i}{\partial B_j^i} \\ \frac{\partial x_j^i}{\partial E_j} &= \frac{\partial \tilde{x}_j^i}{\partial E_j} - \Omega_{j,j}^i \frac{\partial x_j^i}{\partial B_j^i} \\ \frac{\partial \tilde{c}_j^i}{\partial E_j} + p_j \frac{\partial \tilde{x}_j^i}{\partial E_j} &= \Omega_{j,j}^i - t_j \frac{\partial \tilde{x}_j^i}{\partial E_j} \end{aligned} \tag{17}$$

Then, by adding and subtracting $\lambda_j[\partial \hat{v}_j^2/\partial B_j^1]\{[\partial v_j^1/\partial E_j]/[\partial v_j^1/\partial B_j^1]\}$ in equation (16), we can use equations (11), (13) and (16) to derive[6]

$$\begin{aligned} 0 &= \sum_{k=1}^{2}[-\gamma_k \sum_i \Omega_{j,k}^i + \lambda_k \frac{\partial \hat{v}_k^2}{\partial B_k^1}(\hat{\Omega}_{j,k}^2 - \Omega_{j,k}^1) + \gamma_k t_k \sum_i \frac{\partial \tilde{x}_k^i}{\partial E_j} \\ &\quad -\mu_k \sum_i \frac{\partial \tilde{x}_k^i}{\partial E_j}] + \mu_j \end{aligned} \tag{18}$$

Finally, by using the short notation $\bar{\lambda}_k = \lambda_k[\partial \hat{v}_k^2/\partial B_k^1]/\gamma_k$, and that the symmetric equilibrium implies $\mu_1 = \mu_2$ and $\gamma_1 = \gamma_2$, we obtain the following result;

Proposition 1 *In a cooperative symmetric equilibrium with pareto efficient mixed taxation, the shadow price of the externality in terms of the government's tax revenues can be written*

$$\frac{\mu_j}{\gamma_j} = \rho_j \sum_k \{\sum_i \Omega_{j,k}^i - \overline{\lambda}_k[\widehat{\Omega}_{j,k}^2 - \Omega_{j,k}^1] - t_k \sum_i \frac{\partial \tilde{x}_k^i}{\partial E_j}\} \tag{19}$$

for $j = 1, 2$, *where* $\rho_j = 1/\{1 - \sum_k \sum_i [\partial \tilde{x}_k^i/\partial E_j]\}$.

Equation (19) extends the shadow price derived by Pirttilä and Tuomala (1997) to apply in a global economy, where the externality generated by each

[6] This procedure is described by Pirttilä and Tuomala (1997).

country affects the wellbeing of consumers in both countries. The first term on the right hand side of equation (19), $\sum_k \sum_i \Omega^i_{j,k} > 0$, measures the sum of the individuals´ marginal willingness to pay to avoid the externality. This part of equation (19) takes the same general form as the shadow price of the externality in a first best cooperative equilibrium.

The second term, $-\sum_k \bar{\lambda}_k[\hat{\Omega}^2_{j,k} - \Omega^1_{j,k}]$, reflects the influence of the self-selection constraints. More specifically, note that the self-selection constraints of both countries will in general affect the shadow price of the externality facing country j. This provides an interesting link between the countries: the desire to make mimicking less attractive in a particular country will influence the shadow price facing the other country in the cooperative equilibrium. The sign of the second term depends on whether a true type 1 is willing to pay more or less than the mimicker to avoid the externality. If $\partial\Omega^i_{j,k}/\partial l^i_j < 0$, meaning that the marginal willingness to pay to avoid the externality increases with leisure, and since $\bar{\lambda}_k > 0$, the contribution of each self-selection constraint will be to reduce μ_j/γ_j. If, on the other hand, the marginal willingness to pay to avoid the externality decreases with leisure, each self-selection constraint will contribute to increase μ_j/γ_j. Finally, the term $-\sum_k t_k \sum_i(\partial\tilde{x}^i_k/\partial E_j)$ shows how the externality caused by country j affects the revenues from commodity taxation in both countries via changes in each tax base. Note also that the 'feedback-parameter', ρ_j, must be positive in order to guarantee stability of the model, which has been pointed out by Sandmo (1980).

3.2 Commodity tax

We next derive an expression for the optimal commodity-tax on the dirty consumption good. The starting point is the necessary condition for q_j given by equation (15). By recognizing that $\partial v^i_j/\partial q_j = -[\partial v^i_j/\partial B^i_j]x^i_j$, we can solve equations (11) and (13) for $-[\partial v^1_j/\partial B^1_j]x^1_j$ and $-[\delta_j + \lambda_j][\partial v^2_j/\partial B^2_j]x^2_j$, respectively, and substitute into equation (15). Then, by applying the Slutsky condition and noting that $t_j = q_j - p_j$, we obtain the following result;

Proposition 2 *A symmetric cooperative equilibrium with pareto efficient taxation requires that*

$$t_j = \frac{\bar{\lambda}_j}{\sum_i \left[\partial \tilde{x}_j^i / \partial q_j\right]} \left[x_j^1 - \hat{x}_j^2\right] + \frac{\mu_j}{\gamma_j} \tag{20}$$

Equation (20) provides an implicit expression for the tax rate, which consists of two parts. The first part shows the formula for the commodity tax that would apply in the absence of any externalities. Since $\overline{\lambda}_j > 0$ and $\partial \tilde{x}_j^i / \partial q_j < 0$ for $i = 1, 2$, the sign of this term depends on whether a true type 1 consumes more or less of the dirty consumption good than the mimicker. Edwards et al. (1994) analyze this aspect of commodity taxation in detail. The second part is the shadow price of the externality. The difference between equation (20) and the corresponding tax formula in case the externalities constitute pure national problems (i.e. in the absence of transboundary effects of environmental damage) is that the shadow price of the externality implicit in equation (20) reflects how the environmental damage caused by country j affects both countries.

Most previous studies on global externalities disregard other tax distortions. Indeed, if the government is able to observe ability types, lump-sum taxation would be a feasible policy option and the first best becomes a natural reference case. Propositions 1 and 2 then suggest that the commodity tax reduces to read $t_j = \sum_k \sum_i \Omega_{j,k}^i$, which is the formula for a Pigouvian tax under global externalities (see e.g. van der Ploeg and de Zeeuw (1992) and Aronsson and Löfgren (2000)). By comparing this 'first best tax rule' with equation (20), it becomes clear that the nature of externality based taxation is very much dependent upon the whole set of policy instruments. According to equations (19) and (20), measuring the shadow price of the externality created by country j does not only require information about how much the consumers in both countries are willing to pay to avoid this externality. It also requires knowledge about whether this marginal willingness to pay increases or decreases with leisure, and how E_j affects the consumption of dirty goods in both countries.

3.3 'Effective' Marginal Tax Rates

The total tax payment of type i in country j is given by

$$\tau_j(Y_j^i) = T_j(Y_j^i) + t_j x_j^i(q_j, Y_j^i - T_j(Y_j^i), Y_j^i, g_j, E_j, E_k)$$

in which we have used $B_j^i = Y_j^i - T_j(Y_j^i)$. By differentiating with respect to Y_j^i and rearranging, we have

$$\frac{\partial \tau_j(Y_j^i)}{\partial Y_j^i} = 1 - \frac{\partial c_j^i}{\partial Y_j^i} - p_j \frac{\partial x_j^i}{\partial Y_j^i} + \frac{\partial v_j^i / \partial Y_j^i}{\partial v_j^i / \partial B_j^i}[\frac{\partial c_j^i}{\partial B_j^i} + p_j \frac{\partial x_j^i}{\partial B_j^i}] \qquad (21)$$

Equation (21) gives the effective marginal tax rate on a general form and has been derived by e.g. Edwards et al. (1994). By using equations (10)-(13) and (21), it is straight forward to show that the effective marginal tax rates can be written as

$$\frac{\partial \tau_j(Y_j^1)}{\partial Y_j^1} = \overline{\lambda}_j [\frac{\partial \widehat{v}_j^2 / \partial Y_j^1}{\partial \widehat{v}_j^2 / \partial B_j^1} - \frac{\partial v_j^1 / \partial Y_j^1}{\partial v_j^1 / \partial B_j^1}] + \frac{\mu_j}{\gamma_j}[\frac{\partial x_j^1}{\partial Y_j^1} - \frac{\partial v_j^1 / \partial Y_j^1}{\partial v_j^1 / \partial B_j^1} \frac{\partial x_j^1}{\partial B_j^1}]$$

$$\frac{\partial \tau_j(Y_j^2)}{\partial Y_j^2} = \frac{\mu_j}{\gamma_j}[\frac{\partial x_j^2}{\partial Y_j^2} - \frac{\partial v_j^2 / \partial Y_j^2}{\partial v_j^2 / \partial B_j^2} \frac{\partial x_j^2}{\partial B_j^2}]$$

which are analogous to the formulas derived by Pirttilä and Tuomala (1997) in the context of a 'one-country' economy. The only difference is that the effective marginal tax rates are evaluated in a cooperative equilibrium, where the shadow price of the externality relevant for country j is dependent upon how E_j influences consumption and welfare in both countries.

4 A Noncooperative Equilibrium

This section concerns the 'conditionally optimal' tax policies that will arise in a noncooperative equilibrium, where each country is acting as a Nash-competitor. Thus, we now assume that each country chooses its tax and expenditure policies in isolation, and that each 'national' policy maker treats the decision variables of the other country as exogenous.

The objective of each national policy maker is to maximize the utility of the low ability type subject to four restrictions. The constraint that there must be a minimum utility level for the high ability type and the self-selection constraint are analogous to their counterparts in Section 3. However, in the noncooperative framework, it is no longer possible to suppress the mobility incentives, since each country solves its tax and provision problem conditional on the policies chosen by the other country. By normalizing the population of each ability type to equal one prior to migration, the budget constraint facing the policy maker in country j can be written

$$Y_j^1 + [1 - M_j]Y_j^2 - c_j^1 - p_j x_j^1 - [1 - M_j][c_j^2 + p_j x_j^2] - r_j g_j = 0 \qquad (22)$$

where $c_j^i = c_j^i(q_j, B_j^i, Y_j^i, g_j, E_j, E_k)$, $x_j^i = x_j^i(q_j, B_j^i, Y_j^i, g_j, E_j, E_k)$. Migration also affects the form of the externality constraint

$$E_j = x_j^1(\cdot) - \{1 - M_j(\cdot)\}x_j^2(\cdot) \qquad (23)$$

The Lagrangean corresponding to the policy maker's optimization problem becomes

$$\begin{aligned} L_j \;=\; & v_j^1(\cdot) + \delta_j[v_j^2(\cdot) - \bar{v}_j^2] + \lambda_j[v_j^2(\cdot) - \hat{v}_j^2(\cdot)] \\ & + \gamma_j[Y_j^1 + \{1 - M_j(\cdot)\}Y_j^2 - c_j^i(\cdot) - p_j x_j^1(\cdot) \\ & - \{1 - M_j(\cdot)\}\{c_j^2(\cdot) + p_j x_j^2(\cdot)\} - r_j g_j] \\ & + \mu_j[E_j - x_j^1(\cdot) - \{1 - M_j(\cdot)\}x_j^2(\cdot)] \end{aligned}$$

The optimal tax and expenditure policies can be derived by maximizing the Lagrangean with respect to Y_j^1, B_j^1, Y_j^2, B_j^2, g_j, q_j and E_j. In addition to equations (6), (7), (8), (22) and (23), the first order conditions are

$$\frac{\partial v_j^1}{\partial Y_j^1} - \lambda_j \frac{\partial \hat{v}_j^2}{\partial Y_j^1} + \gamma_j [1 - \frac{\partial c_j^1}{\partial Y_j^1} - p_j^x \frac{\partial x_j^1}{\partial Y_j^1}] - \mu_j \frac{\partial x_j^1}{\partial Y_j^1} = 0 \tag{24}$$

$$\frac{\partial v_j^1}{\partial B_j^1} - \lambda_j \frac{\partial \hat{v}_j^2}{\partial B_j^1} - \gamma_j [\frac{\partial c_j^1}{\partial B_j^1} + p_j \frac{\partial x_j^1}{\partial B_j^1}] - \mu_j \frac{\partial x_j^1}{\partial B_j^1} = 0 \tag{25}$$

$$(\delta_j + \lambda_j) \frac{\partial v_j^2}{\partial Y_j^2} + \gamma_j [1 - M_j] \{[1 - \frac{\partial c_j^2}{\partial Y_j^2} - p_j \frac{\partial x_j^2}{\partial Y_j^2}] - \mu_j \frac{\partial x_j^2}{\partial Y_j^2}\} + \frac{\partial M_j}{\partial Y_j^2} Z_j^2 = 0 \tag{26}$$

$$(\delta_j + \lambda_j) \frac{\partial v_j^2}{\partial B_j^2} - \gamma_j [1 - M_j] \{[\frac{\partial c_j^2}{\partial B_j^2} + p_j \frac{\partial x_j^2}{\partial B_j^2}] - \mu_j \frac{\partial x_j^2}{\partial B_j^2}\} + \frac{\partial M_j}{\partial B_j^2} Z_j^2 = 0 \tag{27}$$

$$\begin{aligned} 0 \;=\; & \frac{\partial v_j^1}{\partial g_j} + (\delta_j + \lambda_j) \frac{\partial v_j^2}{\partial g_j} - \lambda_j \frac{\partial \hat{v}_j^2}{\partial g_j} - \gamma_j [\frac{\partial c_j^1}{\partial g_j} + p_j \frac{\partial x_j^1}{\partial g_j} \\ & + \{1 - M_j\} \{\frac{\partial c_j^2}{\partial g_j} + p_j \frac{\partial x_j^2}{\partial g_j}\} + r_j] - \mu_j [\frac{\partial x_j^1}{\partial g_j} + \{1 - M_j\} \frac{\partial x_j^2}{\partial g_j}] + \frac{\partial M_j}{\partial g_j} Z_j^2 \end{aligned} \tag{28}$$

$$\begin{aligned} 0 \;=\; & \frac{\partial v_j^1}{\partial q_j} + (\delta_j + \lambda_j) \frac{\partial v_j^2}{\partial q_j} - \lambda_j \frac{\partial \hat{v}_j^2}{\partial q_j} - \gamma_j [\frac{\partial c_j^1}{\partial q_j} + p_j \frac{\partial x_j^1}{\partial q_j} + \\ & \{1 - M_j\} \{\frac{\partial c_j^2}{\partial q_j} + p_j \frac{\partial x_j^2}{\partial q_j}\}] - \mu_j [\frac{\partial x_j^1}{\partial q_j} + \{1 - M_j\} \frac{\partial x_j^2}{\partial q_j}] + \frac{\partial M_j}{\partial q_j} Z_j^2 \end{aligned} \tag{29}$$

$$\begin{aligned} 0 \;=\; & \frac{\partial v_j^1}{\partial E_j} + (\delta_j + \lambda_j) \frac{\partial v_j^2}{\partial E_j} - \lambda_j \frac{\partial \hat{v}_j^2}{\partial E_j} - \gamma_j [\frac{\partial c_j^1}{\partial E_j} + p_j \frac{\partial x_j^1}{\partial E_j} + \\ & \{1 - M_j\} \{\frac{\partial c_j^2}{\partial E_j} + p_j \frac{\partial x_j^2}{\partial E_j}\}] + \mu_j - \mu_j [\frac{\partial x_j^1}{\partial E_j} + \{1 - M_j\} \frac{\partial x_j^2}{\partial E_j}] + \frac{\partial M_j}{\partial E_j} Z_j^2 \end{aligned} \tag{30}$$

where $j = 1, 2$, and $Z_j^2 = \gamma_j [-Y_j^2 + c_j^2 + p_j x_j^2] + \mu_j x_j^2$.

Suppose that

$$\Phi_j^n = (Y_j^{1,n}, B_j^{1,n}, Y_j^{2,n}, B_j^{2,n}, g_j^n, q_j^n, E_j^n)$$

solve planner j's optimization problem, where the superindex "n" is used as a short notation for the noncooperative equilibrium. We define (Φ_1^n, Φ_2^n) to be a noncooperative Nash-equilibrium if Φ_1^n is optimal for country 1 conditional on $\Phi_2 = \Phi_2^n$, and Φ_2^n is optimal for country 2 conditional on $\Phi_1 = \Phi_1^n$. In what follows, we assume that the countries have reached the noncooperative Nash-equilibrium and drop the superindex "n" to simplify the notations. To be able to compare the results with those of Section 3, we also assume that the shadow prices corresponding to the self-selection constraint and the government's budget constraint are strictly positive, i.e. $\lambda_j > 0$ and $\gamma_j > 0$ at the equilibrium.

Since the two countries are identical, their tax and expenditure policies will be identical in equilibrium. We therefore concentrate the analysis to the representative country, which will be indexed by "j". Since the two countries are identical, there will be no migration in equilibrium, i.e. $M_j(\cdot) = 0$. However, the incentives related to migration are, nevertheless, important in the sense of influencing the decisions taken by each national government.

4.1 Shadow price of externalities

As in Section 3, we define $\Omega_{j,j}^i = -[\partial v_j^i/\partial E_j]/[\partial v_j^i/\partial B_j^i]$ as the marginal willingness to pay by type i to avoid the domestically created externality. Similarly, we denote the Hicksian demands for clean and dirty consumption goods by $\tilde{c}_j^i$ and $\tilde{x}_j^i$, respectively. Then, by adding and subtracting $\lambda_j[\partial \hat{v}_j^2/\partial B_j^1]\{[\partial v_j^1/\partial E_j]/[\partial v_j^1/\partial B_j^1]\}$ in equation (30), we can use equations (25), (27) and (30) to derive

$$
\begin{aligned}
0 \;=\; & -\mu_j[1-\sum_i \frac{\partial \tilde{x}_j^i}{\partial E_j} + \{\frac{\partial M_j}{\partial E_j} + \frac{\partial M_j}{\partial B_j^2}\Omega_{j,j}^2\}x_j^2] + \gamma_j \sum_i \Omega_{j,j}^i \\
& -\lambda_j \frac{\partial \hat{v}_j^2}{\partial B_j^1}[\hat{\Omega}_{j,j}^2 - \Omega_{j,j}^1] - \gamma_j t_j \sum_i \frac{\partial \tilde{x}_j^i}{\partial E_j} + [\frac{\partial M_j}{\partial E_j} + \frac{\partial M_j}{\partial B_j^2}\Omega_{j,j}^2]\gamma_j \tau_j^2
\end{aligned} \tag{31}
$$

where $\tau_j^2 = Y_j^2 - c_j^2 - p_j x_j^2$ is the total tax payment of type 2. Equation (31) implicitly defines the equilibrium shadow price of the domestically created externality. By observing from equation (6) that

$$
\partial M_j/\partial E_j + (\partial M_j/\partial B_j^2)\Omega_{j,j}^2 = [\partial v_k^2/\partial E_j]/d',
$$

and then using the short notation $\bar{\lambda}_j = \lambda_j[\partial \hat{v}_j^2/\partial B_j^1]/\gamma_j$, we can derive the following result;

Proposition 3 *In a noncooperative symmetric equilibrium with pareto efficient mixed taxation, the shadow price of the externality in terms of the government's tax revenues can be written*

$$
\frac{\mu_j}{\gamma_j} = \sigma_j\{\sum_i \Omega_{j,j}^i - \overline{\lambda}_j[\widehat{\Omega}_{j,j}^2 - \Omega_{j,j}^1] - t_j \sum_i \frac{\partial \tilde{x}_j^i}{\partial E_j} + \frac{\partial v_k^2/\partial E_j}{d'}\tau_j^2\} \tag{32}
$$

for $j = 1, 2$, *where* $\sigma_j = 1/\{1 - \sum_i[\partial \tilde{x}_j^i/\partial E_j] + \{[\partial v_k^2/\partial E_j]/d'\}x_j^2\}$.

Even if migration is zero in the symmetric equilibrium, the incentives related to migration will, nevertheless, affect μ_j/γ_j. In comparison with the shadow price obtained in the cooperative equilibrium, equation (32) contains two additional terms, both of which are proportional to the marginal disutility of migration, $d'(\cdot)$, facing the high ability type. First, the higher the consumption of dirty goods by the high ability type, the greater will be the domestically created environmental damage. Since out-migration reduces the aggregate consumption of the dirty good, there will be an incentive for the national government to induce out-migration via higher effective marginal tax rates. This effect works to increase σ_j and, therefore, to increase the shadow price of the domestically created externality in terms of the government's tax revenues. Second, out-migration of high ability types reduces the tax base. To avoid a loss of tax base, the government will have incentives to reduce the marginal tax rates by lowering the value of μ_j/γ_j. This effect is captured by the final term on the right hand side of the formula in the proposition. The remaining terms in the expression for μ_j/γ_j reflect, respectively, the marginal willingness to pay to avoid the externality, the self-selection constraint and the impact of E_j on the consumption of dirty goods. An important difference in comparison with the outcome of the cooperative equilibrium is that the latter three terms only refer to country j: the corresponding effects of E_j on the other country are absent in the noncooperative equilibrium.

4.2 Commodity Taxation

By applying the same procedure as in the derivation of the commodity tax in the cooperative equilibrium, while at the same time using equation (6) to establish that

$$\frac{\partial M_j}{\partial q_j} + \frac{\partial M_j}{\partial B_j^2} x_j^2 = 0,$$

we can derive the following result;

Proposition 4 *A noncooperative symmetric equilibrium with pareto efficient taxation requires that*

$$t_j = \frac{\bar{\lambda}_j}{\sum_i [\partial \tilde{x}_j^i / \partial q_j^x]} [x_j^1 - \hat{x}_j^2] + \frac{\mu_j}{\gamma_j} \qquad (33)$$

The expression for the commodity tax on the dirty consumption good takes the same general form as in the cooperative equilibrium. Nevertheless, the two tax formulas are different in general, since the way in which the shadow price of the externality is being measured differs between the regimes. A natural next question is whether the commodity tax on the dirty consumption good in the noncooperative equilibrium exceeds, or falls short of, that corresponding to the cooperative equilibrium. Without further assumptions, the difference between the two taxes can go in either direction. To see this, consider first a simplified version of the model where the high ability types are immobile, and the utility functions are separable in the sense that $u(c_j^i, x_j^i, l_j^i, g_j, E_j, E_k) = \phi(\varphi(c_j^i, x_j^i, g_j), l_j^i, E_j, E_k)$ for $i = 1,2,\ j = 1,2$ and $k \neq j$. The two tax formulas reduce to read

$$t_j^n = \sum_i \Omega_{j,j}^{i,n}$$

$$t_j^* = \sum_k \sum_i \Omega_{j,k}^{i,*}$$

where the superindices "n" and "$*$" refer to, respectively, the noncooperative and cooperative equilibrium. Then, if the sum of the marginal willingness to pay to avoid the externality is a monotonous function of the commodity tax rate, it trivially follows that the cooperative equilibrium implies a higher tax than the noncooperative equilibrium. However, by relaxing the assumption that the high ability types are immobile, this comparison becomes inconclusive. This is so because the mobility incentives facing the high ability types may change the commodity tax corresponding to the noncooperative equilibrium in either direction compared to the case when the high ability types are immobile. Similarly, by relaxing the assumption that leisure is separable from the other goods, the self-selection constraints become operative in the tax formulas. Since the qualitative effect of the self-selection constraints is ambiguous, and since each country's commodity tax depends on all countries' self-selection constraints in the cooperative equilibrium, one cannot rule out the possibility that the self-selection constraints work to reduce the commodity tax in the cooperative equilibrium relative to that in the noncooperative equilibrium. As a consequence, the commodity tax in the noncooperative equilibrium is not necessarily chosen to be lower than what is optimal from society's point of view. We will return to this issue in Section 6 by analyzing the welfare effects of a commodity tax reform in the noncooperative equilibrium.

4.3 Effective Marginal Tax Rates

By using equations (24)-(27) and (21), it is straight forward to show that the formulas for the effective marginal tax rates of both ability types closely resemble the formulas derived in the cooperative equilibrium. The most important differences between the cooperative and noncooperative regimes refer to the way in which the shadow price of the externality is being calculated. These differences arise because (i) the welfare of the 'other country' is not part of the national policy makers' objective functions in the noncooperative framework, and (ii) the parameters of the migration function influence the first order conditions corresponding to the noncooperative equilibrium.

5 Implementation of the Cooperative Equilibrium

Is it possible to implement the cooperative equilibrium in a decentralized setting, where each individual country is allowed to choose its preferred tax and expenditure policies? The answer to this question is yes, provided that a 'federal' government is able to correct the choices made by each national government. Recall that the formal differences between the equilibria discussed in the previous two sections refer to the first order conditions for E_j, Y_j^2, B_j^2, g_j and q_j. The necessary condition obeyed by E_j differs between the two equilibria because of uninternalized spillover effects of environmental damage and mobility incentives in the noncooperative equilibrium, whereas the mobility incentives alone make the conditions for Y_j^2, B_j^2, g_j and q_j differ between equilibria. Therefore, to be able to implement the cooperative equilibrium in a framework where each individual country acts in accordance with the noncooperative model, the federal government must be able to alter the national government's own choices of these five decision variables.

Suppose that the federal government imposes taxes/subsidies proportional to E_j, Y_j^2, B_j^2, g_j and q_j, which means that the national government's budget constraint can be written as

$$\begin{aligned} 0 &= Y_j^1 + [1 - M_j]Y_j^2 - c_j^1 - p_j x_j^1 - [1 - M_j][c_j^2 + p_j x_j^2] - r_j g_j \\ &\quad + \Gamma_j - \theta_j^E E_j - \theta_j^Y Y_j^2 - \theta_j^B B_j^2 - \theta_j^g g_j - \theta_j^q q_j \qquad (34) \end{aligned}$$

where $j = 1, 2$, and Γ_j is a lump-sum transfer received by (or a country specific fee paid by) country j. The federal government's budget constraint takes the form

$$\sum_j [\Gamma_j - \theta_j^E E_j - \theta_j^Y Y_j^2 - \theta_j^B B_j^2 - \theta_j^g g_j - \theta_j^q q_j] = 0 \qquad (35)$$

To be able to describe the federal government's policy as clearly as possible, let us denote the cooperative equilibrium by the superindex "*". In addition, even if there are no incentives related to migration in this cooperative equilibrium, we use derivatives like e.g. $\partial M_j^* / \partial E_j$, etc., to measure derivatives of the migration function which are evaluated in the cooperative equilibrium. Finally, to shorten the notations, let

$$\begin{aligned} \Lambda_{j,k} &= \frac{\partial v_k^1}{\partial E_j} + (\delta_k + \lambda_k)\frac{\partial v_k^2}{\partial E_j} - \lambda_k \frac{\partial \widehat{v}_k^2}{\partial E_j} - \gamma_k \sum_i [\frac{\partial c_k^i}{\partial E_j} + p_k \frac{\partial x_k^i}{\partial E_j}] \\ &\quad - \mu_k \sum_i \frac{\partial x_k^i}{\partial E_j} - \frac{\partial M_j}{\partial E_j} Z_j^2 \end{aligned}$$

represent the terms by which the form of first order condition for E_j differs between the cooperative and noncooperative regimes. Consider the following result;

Proposition 5 *If the federal government chooses tax/subsidy rates according to*

$$\theta_j^E = -\Lambda_{j,k}^* / \gamma_j^*$$

$$\theta_j^Y = \frac{[\partial M_j^* / \partial Y_j^2] Z_j^{2,*}}{\gamma_j^*}$$

$$\theta_j^B = \frac{[\partial M_j^* / \partial B_j^2] Z_j^{2,*}}{\gamma_j^*}$$

$$\theta_j^g = \frac{[\partial M_j^* / \partial g_j] Z_j^{2,*}}{\gamma_j^*}$$

$$\theta_j^q = \frac{[\partial M_j^* / \partial q_j] Z_j^{2,*}}{\gamma_j^*}$$

for $j = 1, 2$*, and uses the lump-sum transfer (or national fee to the federation) to balance the national budget constraints, the noncooperative equilibrium will coincide with the cooperative equilibrium.*

The proof of Proposition 5 is straight forward. Suppose that each national planner acts in accordance with the framework set out in Section 4, and chooses B_j^1, B_j^2, Y_j^1, Y_j^2, g_j, q_j and E_j to maximize the utility of the low ability type subject to equations (6), (7), (8), (23) and (34). By evaluating the resulting first order conditions at the symmetric cooperative equilibrium, it follows that these first order conditions (which are derived in a noncooperative framework) will coincide with those formally derived in the context of the symmetric cooperative equilibrium.

Note that, to implement the cooperative equilibrium in a decentralized setting, where each individual country chooses its own tax and expenditure policies, the federal government must solve the second best problem at the global level described in Section 3. The federal government can then design the policy instruments required to make the national governments choose the cooperative equilibrium as their preferred outcome. Since the two countries are identical in all important respects, the taxes/subsidies imposed by the federal government are the same for both countries.

6 A Different View on 'Cooperation'

Clearly, even if it in principle is possible to implement the cooperative equilibrium in a decentralized framework, the federal government would require a large set of policy instruments. In practice, however, 'cooperation' is not likely to mean that different countries pool their resources in order to implement a socially optimal resource allocation on a global level. Following Aronsson et al. (2000), it is equally important (and far more realistic) to view 'cooperation over environmental policy' as a policy project, the purpose of which is to improve the resource allocation in comparison with the initial equilibrium, in which no such cooperation takes place.

In this section, we assume that the initial (prereform) equilibrium is given by the symmetric noncooperative equilibrium of Section 4. The purpose is then to study the welfare effects that will arise, if the countries agree to slightly raise their commodity taxes. To operationalize the idea of a 'cooperative policy project', suppose that the countries decide to form a 'federal government', and that the federal government imposes a (positive or negative) uniform tax on the dirty consumption good which is added to the national rates. The national governments also agree not to change their commodity taxes in response to the federal commodity tax. The tax revenues collected from country j via the federal commodity tax are payed back to country j via a transfer payment to the national government. The federal government's budget constraint can be written as

$$\alpha[x_j^1 + x_j^2] - R_j(\alpha) = 0 \tag{36}$$

for $j = 1, 2$, where α (which is assumed to be small) is the commodity tax chosen by the federal government, and $R_j(\cdot)$ is a transfer payment from the federal government to the (national) government of country j. An explicit assumption of fiscal neutrality at the national level simplifies the calculations without affecting the results. This is so because the prereform equilibrium is symmetric, which means that the transfer payments from the federal to the national governments will be of equal size.

To simplify the notations as much as possible, let

$$\begin{aligned} L_j &= v_j^1 + \delta_j[v_j^2 - \overline{v}_j^2] + \lambda_j[v_j^2 - \widehat{v}_j^2] + \gamma_j[\sum_i Y_j^i - \sum_i c_j^i - p_j \sum_i x_j^i - g_j] \\ &\quad + \mu_j[E_j - \sum_i x_j^i] \end{aligned} \tag{37}$$

be the Lagrangean of country j evaluated in the symmetric noncooperative equilibrium, and define the short notation

$$\begin{aligned} \frac{\partial L_j}{\partial E_k} &= \frac{\partial v_j^1}{\partial E_k} + \delta_j \frac{\partial v_j^2}{\partial E_k} + \lambda_j[\frac{\partial v_j^2}{\partial E_k} - \frac{\partial \widehat{v}_j^2}{\partial E_k}] - \gamma_j[\sum_i \frac{\partial c_j^i}{\partial E_k} + p_j \sum_i \frac{\partial x_j^i}{\partial E_k}] \\ &\quad - \mu_j \sum_i \frac{\partial x_j^i}{\partial E_k} \end{aligned}$$

which will be used in the analysis below. The value function facing the federal government is the sum of the country-specific objective functions evaluated in the noncooperative equilibrium. It will be convenient to write the value function in terms of the equilibrium values of the national policy instruments. By using equation (37), the value function can be written as;

$$V = \sum_j v_j^1 = \sum_j L_j(q_j + \alpha, B_j^1(\alpha), Y_j^1(\alpha), B_j^2(\alpha), Y_j^2(\alpha), g_j(\alpha), E_j(\alpha), E_k(\alpha)) \tag{38}$$

for $k \neq j$, in which the value of α is zero prior to the reform. The superindex "n" (for noncooperative equilibrium) has been suppressed for notational convenience. Note also that the national policy variables and externalities caused by national policies (i.e. B_j^1, Y_j^1, B_j^2, Y_j^2, g_j, E_j and E_k) are functions of α, since the national policy decisions are being made conditional on the choices of the federal government.

The cost benefit rule we are looking for can be derived by differentiating the value function in equation (38) with respect to α and then evaluating the resulting derivative at the point where $\alpha = 0$. The reader should note that this policy reform will affect the welfare level only because the prereform equilibrium is suboptimal from society's point of view. It is, therefore, convenient to write the cost benefit rule for α in terms of mobility incentives and transboundary externalities, which are the causes of suboptimality in the noncooperative equilibrium. This is addressed in Proposition 6, which is formally derived in the Appendix;

Proposition 6 *The welfare effect of introducing a small federal commodity tax on the dirty good in the symmetric noncooperative equilibrium, when the national commodity taxes are held constant, can be written*

$$\begin{aligned}\frac{\partial V}{\partial \alpha} &= \sum_j \{-Z_j^2[\frac{\partial M_j}{\partial q_j} + \frac{\partial M_j}{\partial g_j}\frac{\partial g_j}{\partial \alpha} + \frac{\partial M_j}{\partial E_j}\frac{\partial E_j}{\partial \alpha}] \\ &\quad + \frac{\partial L_j}{\partial E_k}\frac{\partial E_k}{\partial \alpha}\}\end{aligned} \tag{39}$$

for $k \neq j$.

In general, the welfare effect of this policy reform can go in either direction. An interpretation is that a shift from national to federal commodity taxation does not necessarily imply higher commodity taxes, even if national commodity taxation does not fully internalize the externality. Equation (39) is useful in the sense of showing what information we would require in order to determine the welfare effect of increased or decreased commodity taxation in the noncooperative equilibrium. These informational requirements include: (i) how the national policies affect migration, (ii) how the national policies respond to federal commodity taxation and (iii) the welfare effects arising via the transboundary part of the externality.

The terms in the first row on the right hand side of equation (39) are due to the mobility incentives underlying the national governments' policy decisions in the noncooperative equilibrium. Note that the derivatives of the migration function are proportional to the variable $Z_j^2 = -\gamma_j \tau_j^2 + \mu_j x_j^2$, where τ_j^2 is the total tax payment made by a type 2 individual. Therefore, as expected from Section 4, the welfare effects arising via the derivatives of the migration function depend on whether the mobility incentives implicit in the noncooperative equilibrium make the national governments choose 'too much' or 'too little' commodity taxation.

Consider first what happens when $Z_j^2 < 0$; a situation that may arise e.g. when the consumption of dirty goods by type 2 is negligible. This means that the national governments' decisions about commodity taxation reflect the incentive to reduce out-migration or cause in-migration, implying that the prereform commodity taxes are relatively low. Increasing the commodity taxes will then increase the welfare level via the term $\partial M_j / \partial q_j = \partial M_j / \partial \alpha > 0$. However, provided that $\partial g_j / \partial \alpha \geq 0$ and $\partial E_j / \partial \alpha \leq 0$ (which may appear to be reasonable assumptions), the remaining terms in the first row will not contribute to increase the welfare level, since higher public expenditures and less domestic environmental damage tend to strengthen the (incorrect) mobility incentives characterizing the policy in the initial equilibrium. If, on the other hand, $Z_j^2 > 0$, the arguments will go the other way around. Finally, the term in the second row of equation (39) is the direct spillover effect of environmental damage times the impact of the federal commodity tax on the externality caused by the other country.

Note finally that in the absence of preexisting distortions, the welfare effect of this tax reform will be equal to zero. This is seen by calculating the corresponding cost benefit rule for the cooperative equilibrium, where mobility incentives have no influence over national tax policies, and the spillover effect of environmental damage is optimally chosen from society's point of view.

7 Summary and Discussion

This paper addresses transboundary environmental problems and labor mobility in the context of an optimal tax problem for a two-country economy. Each individual country is represented by a two type model, where the ability of a given individual cannot be observed by the policy maker, and the tax instruments include commodity taxation and nonlinear income taxation. The analysis is based on the assumptions that (i) high ability types are mobile whereas the low ability types are not, and (ii) the environmental damage caused by each country spills over to the other country. The main purpose of the paper is to compare the 'conditionally optimal' second best policy that will arise in a noncooperative equilibrium with the outcome of cooperation.

Even if the two countries are identical by assumption, implying that migration is equal to zero, the mobility incentives facing the high ability type will affect the optimal tax policy in the noncooperative equilibrium. This influence arises via the shadow price of the domestically created externality, and two separate effects can be identified. First, out-migration of high ability types reduces the tax base. To avoid a loss of tax base, the national government will have an incentive to lower the implicit shadow price of the externality and, therefore, reducing the commodity tax and the effective marginal tax rate. Second, out-migration also reduces the aggregate consumption of the dirty good, which makes the externality less severe for domestic consumers. This provides an environmental benefit from the point of view of the national government and tends to increase the shadow price of the externality.

Mobility incentives have no influence over tax policy in the symmetric cooperative equilibrium, since the 'global policy maker' recognizes that the two countries are identical and can, therefore, anticipate that migration will be equal to zero. In the cooperative equilibrium, the shadow price of the externality facing each country reflects all welfare effects (both domestically and abroad) of the environmental damage generated by that particular country. However, contrary to most previous studies on global externalities, the optimal commodity tax is not directly interpretable as a 'full' Pigouvian tax reflecting the sum of the willingness to pay to reduce the externality. This is so because the 'Samuelsonian sum of willingness to pay' is only one part of the shadow price of the externality in the cooperative equilibrium and, therefore, only part of the optimal commodity tax. The shadow price of the externality facing each country will also reflect the self-selection constraint and the consumption of dirty goods in the other country. This is clearly different from results in studies where the first best cooperative equilibrium constitutes the reference case, which suggests that the optimal 'environmental tax' required to internalize transboundary externalities is dependent upon the whole set of policy instruments in all countries involved.

It is (in principle) possible to implement the cooperative equilibrium in a decentralized setting, where each national policy maker acts in accordance with the noncooperative model. This can be accomplished by allowing a 'federal government' to provide correct incentives for the national policy makers. However, it is important to note that the federal policy maker must be allowed to possess several nonstandard policy instruments in order to achieve the cooperative outcome in a decentralized setting. It is, therefore, more realistic to view 'cooperation over environmental policy' as a policy project, the purpose of which is to improve the resource allocation in comparison with the initial equilibrium. The final part of the paper addresses the welfare consequences of cooperation over the commodity tax by allowing a federal government to add a commodity tax on top of the national commodity taxes. The prereform situation is represented by the noncooperative equilibrium. We show how the welfare effects of this reform is related to the transboundary externality and mobility incentives, which are the causes of suboptimality in the noncooperative equilibrium.

8 Appendix

Proof of Proposition 6:

By differentiating the value function in equation (38) with respect to α, we have

$$\begin{aligned}\frac{\partial V}{\partial \alpha} &= \sum_j [\frac{\partial L_j}{\partial q_j} + \frac{\partial L_j}{\partial B_j^1}\frac{\partial B_j^1}{\partial \alpha} + \frac{\partial L_j}{\partial Y_j^1}\frac{\partial Y_j^1}{\partial \alpha} + \frac{\partial L_j}{\partial B_j^2}\frac{\partial B_j^2}{\partial \alpha} + \frac{\partial L_j}{\partial Y_j^2}\frac{\partial Y_j^2}{\partial \alpha} \\ &\quad + \frac{\partial L_j}{\partial g_j}\frac{\partial g_j}{\partial \alpha} + \frac{\partial L_j}{\partial E_j}\frac{\partial E_j}{\partial \alpha} + \frac{\partial L_j}{\partial E_k}\frac{\partial E_k}{\partial \alpha}]\end{aligned} \quad \text{(A1)}$$

The necessary conditions obeyed by the symmetric noncooperative equilibrium are interpretable in terms of derivatives of the Lagrangean in equation (37). The necessary conditions imply; $\partial L_j/\partial B_j^1 = 0$, $\partial L_j/\partial Y_j^1 = 0$, $\partial L_j/\partial B_j^2 = -[\partial M_j/\partial B_j^2]Z_j^2$, $\partial L_j/\partial Y_j^2 = -[\partial M_j/\partial Y_j^2]Z_j^2$, $\partial L_j/\partial q_j = -[\partial M_j/\partial q_j]Z_j^2$, $\partial L_j/\partial g_j = -[\partial M_j/\partial g_j]Z_j^2$ and $\partial L_j/\partial E_j = -[\partial M_j/\partial E_j]Z_j^2$. Finally, substituting these expressions into equation (A1), while using $B_j^i = Y_j^i - T_j(Y_j^i)$ together with equations (4) and (6) to derive $[\partial M_j/\partial B_j^2][\partial B_j^2/\partial \alpha] = -[\partial M_j/\partial Y_j^2][\partial Y_j^2/\partial \alpha]$, gives equation (39). ■

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