Global Environmental Problems and Actions Taken by Coalitions

by

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Abstract

According to the standard theory of externalities, international public goods like environmental quality would be undersupplied by voluntary contributions of affected countries. The question raised in this paper is whether or not it pays for confederations like the European union to subsidize the contributions of their member states. It is shown that the welfare of the member states increases through the introduction of subsidies if, on the one hand, the marginal propensity to consume the public good outside the confederation is high enough and if, on the other hand, the confederation is sufficiently large in comparison with the rest of the world.

Keywords: Private provision of public goods, subsidies, environmental quality

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I. Introduction

Many serious environmental problems cross national boundaries. Particularly, global environmental problems such as global warming through the greenhouse effect or the effects of emissions on the ozone layer are not restricted to a specific area. At least approximately, only the aggregate emissions not the spatial distribution of emissions determine the environmental quality which has therefore the properties of an international public good. Pollution can be considered as a contribution to a public bad and abatement as a contribution to a public good.

It is often argued that international policy coordination is needed to deal with global environmental problems because the incentives to free-ride are too strong for each country since each country's contribution is small relative to the aggregate emission level [see, e.g., OECD (1993), pp. 79 - 80]. A Nash equilibrium is characterized by serious over-provision of the public bad.

By definition, any unilateral deviation from the Nash equilibrium is harmful for the respective player (country) in the pollution game. It has been shown by Hoel (1991) that under certain circumstances a unilateral environment protection action increases emissions and welfare of neighboring countries while reducing aggregate emissions. The effect on total welfare is unclear, but welfare will unambiguously increase if the unilateral reduction of emissions is taken by the country with the lowest abatement costs. Nevertheless, if countries are unable to sign binding contracts, unilateral actions will not be taken by self-interested countries.

However, Nash equilibria are not coalitionproof. Therefore, the member states of confederations such as the European union can benefit from environment protection policies which are coordinated among themselves. The aim of this paper is to analyze whether the coordinated use of special environmental policy instruments namely subsi-

dies and taxes within a confederation reduces the strictness of the free-rider problem in global environmental problems. Since such instruments will be used only if the member states of the confederation are among the beneficiaries, the main task is to identify those who benefit from environmental subsidies/taxes which are levied at the confederal level.

As mentioned above, the global environmental quality can be considered as a international public good which is or is not voluntary provided. Therefore, we will refer to the body of literature dealing with the voluntary provision of public goods [see among others, Warr (1983), Boadway, Pestieau and Wildasin (1989), and Bergstrom, Blume and Varian (1986)]. In particular, the dual approach used by Ihori (1996) proves to be useful to answer our question.

The paper is organize as follows. Section two develops the model and describes the equilibrium of voluntary public good provision. Section three considers subsidies within a confederation. Using the isomorphism of subsidies and taxes, section four applies the analysis of subsidies to environmental charges. Section five presents a summary and an outlook.

II. The Nash equilibrium

We consider two groups of countries, a confederation and the rest of the world. The confederation consists of n_1 by assumption identical member states, the rest of the world consists of n_2 likewise identical countries which, however, might differ from the member states of the confederation. While the subscript 1 is used to identify a country within the confederation, the subscript 2 indicates the countries outside the confederation. The welfare U^i in a country of type i, $i = 1,2$, is determined by the private consumption c^i and by a pure international public good G:

(1) $\quad U^i = U^i(c^i, G)$.

Both goods are assumed to be normal goods. The amount of the public good is equal to the sum of the voluntary provided quantities

(2) $\quad G = n_1 g_1 + n_2 g_2$,

where g_i denotes the contribution of a country of type i to the international public good.

We assume that in each country the national income Y_i and the relative price p_i of the public good in terms of private consumption, i.e. the productivity of providing public goods, are exogenously given. Outside the confederation the budget restriction is given by

$$c^i + p_2 g_2 = Y_2 . \tag{3}$$

Within the confederation we allow for a confederal subsidy of public good contributions financed through a lump-sum tax T_1. A member state faces therefore the budget constraint

$$c^i + (1 - s_1) p_1 g_1 = Y_1 - T_1 , \tag{4}$$

where s_1 indicates the rate of subsidy. For notational convenience, we define the relative prices of the public good from the national perspective $q_1 := (1 - s_1) p_1$ and $q_2 := p_2$, respectively. Furthermore, the disposable national income is denoted by Y_i^n, so that $Y_1^n = Y_1 - T_1$ and $Y_2^n = Y_2$. Using these definitions, the budget constraint in a country of type i can be written as

$$c^i + q_i G = Y_i^n + q_i (G - g_i) . \tag{5}$$

Since $G - g_i$ is the contribution of all countries with the exception of the country of type i under consideration, the RHS is independent of the public good quantity provided by this particular country. If countries behave in a Nash fashion and take the contributions of other countries as given, private consumption c_i and the total quantity of the pure public good G could be seen as the control variables [this transformation has be used by Bergstrom, Blume and Varian (1986) and many other authors].

It pays to employ the dual approach which has been used in a very similar way by Ihori (1996). The expenditure function $E^i(q_i, U^i)$ is obtained by the minimization of expenditures $E^i = c^i + q_i G$ subject to a utility constraint $U^i = U$. For later use, we stress $E^i_U \equiv q_i G^i_U + c^i_U > 0$ and $G^i_q < 0$, where $c^i(q_i, U^i)$ and $G^i(q_i, U^i) \equiv \partial E^i / \partial q_i$ are the compensated demand functions for private and public consumption, respectively. Fur-

thermore, since public and private consumption are normal goods, $G_U^i > 0$ and $c_U^i > 0$ unambiguously hold.

Using the budget constraint and the definition of the expenditure function,

$$E^i\left(q_i, U^i\right) = Y_i^n + q_i\left(G - g_i\right) \tag{6}$$

holds. Besides, at the equilibrium the public good G is in each country equal to the compensated demand $G^i\left(q_i, U^i\right)$ for the public good. Finally, we assume that each country actually provides some quantity of the public good at the equilibrium.

Altogether, the Nash equilibrium is characterized by

$$\begin{aligned} n_1 q_2 E^1\left(q_1, U^1\right) + n_2 q_1 E^2\left(q_2, U^2\right) - n_1 q_2\left(Y_1 - T_1\right) - n_2 q_1 Y_2 & \\ -\left(n_1 + n_2 - 1\right) q_1 q_2 G^1\left(q_1, U^1\right) = 0, & \\ G^1\left(q_1, U^1\right) - G^2\left(q_2, U^2\right) = 0. & \end{aligned} \tag{7}$$

III. Subsidy

Totally differentiating (7), yields

$$\begin{aligned} &\begin{pmatrix} n_1 q_2 E_U^1 - \left(n_1 + n_2 - 1\right) q_1 q_2 G_U^1 & n_2 q_1 E_U^2 \\ G_U^1 & -G_U^2 \end{pmatrix} \begin{pmatrix} dU^1 \\ dU^2 \end{pmatrix} \\ &+ \begin{pmatrix} n_1 q_2 g_1 - \left(n_1 + n_2 - 1\right) q_1 q_2 G_q^1 \\ G_q^1 \end{pmatrix} dq_1 + \begin{pmatrix} n_1 q_2 \\ 0 \end{pmatrix} dT_1 = 0. \end{aligned} \tag{8}$$

Let us suppose that the confederation encourages voluntary contributions to the international public good through a subsidy which is financed by a lump sum tax. We exclude any international side payments. The budget constraint at the confederal level, therefore, is

$$T_1 = g_1 s_1 p_1 = g_1\left(p_1 - q_1\right). \tag{9}$$

It requires for any change in the level of subsiding

$$dT_1 = s_1 p_1 dg_1 - g_1 dq_1. \tag{10}$$

Furthermore, by definition,

(11) $$dq_1 = -p_1 ds_1 .$$

Inserting (11) and (10) into (8) at $s_1 = 0$, the welfare effects of introducing the budget neutral subsidy can be calculated. For this purpose we define and calculate

(12)
$$\begin{aligned}\Delta &= -\left(n_1 E_U^1 - \left(n_1 + n_2 - 1\right) q_1 G_U^1\right) q_2 G_U^2 - n_2 E_U^2 q_1 G_U^1 \\ &= -n_1 c_U^1 q_2 G_U^2 - n_2 c_U^2 q_1 G_U^1 - q_1 G_U^1 q_2 G_U^2 \\ &< 0.\end{aligned}$$

Since

(13) $$\frac{dU^2}{ds_1} = \frac{n_1 p_1 q_2 E_U^1 G_q^1}{\Delta}$$

is unambiguously positive, the rest of the world benefits from a subsidy within the confederation. In contrast, the sign of

(14) $$\frac{dU^1}{ds_1} = \frac{p_1 q_1 E_U^2 G_q^1}{\Delta}\left(\left(n_1 + n_2 - 1\right)\frac{q_2 G_U^2}{E_U^2} - n_2\right)$$

is ambiguous. The member states themselves, however, profit from the subsidy if

(15) $$\frac{q_2 G_U^2}{E_U^2} > \frac{n_2}{n_1 + n_2 - 1}$$

is fulfilled. The LHS is the marginal propensity to consume the public good in a representative country outside the confederation $d\left(q_2 G^2\right)/dE^2$ and the RHS is approximately the share of the rest of the world in the total population. As the following proposition states:

Proposition 1*: Introducing a lump-sum-tax financed subsidy of contributions to an international public good in a confederation, always increases welfare in the rest of the world, but also increases welfare in the member states if the marginal propensity to consume the public good is sufficiently large in the rest of the world, namely higher than approximately the share of the countries outside the federation in the total population.*

According to the normal good assumption, the LHS is positive but smaller than one since the marginal propensity of private consumption is also non-negative. If $n_1 = 1$, i.e. if the subsidy is a unilateral measure by a single nation, the RHS is always one. Therefore, a single nation will never benefit from an internal subsidy, which is in fact nothing else than a price distortion.

If more than one country introduces a subsidy, not only the outsiders but also the insiders might be among the beneficiaries. Holding the total number of countries $n := n_1 + n_2$ fixed, the larger the confederation is, the smaller is the RHS $(n - n_1)/(n-1)$, which approaches zero as the confederation covers more and more the whole world. Therefore, it is more likely that the member states of a confederation gain from a subsidy if the number of countries which form the coalition is large.

If $n_1 > 1$, the subsidy is not necessarily a harmful price distortion. Rather, each member state benefits from the relative price change, caused by the subsidy, in the other member states.

To figure out this argument more carefully, let us consider the impact of the subsidy on the voluntary contributions. Since $dG/ds_1 = G_U^2 \, dU^2/ds_1 > 0$ holds, the subsidy leads to an increase in the overall public good consumption. From the fact that the rest of the world benefits from the subsidy and that the relative price does not change outside the confederation, one can conclude that the subsidy shifts the budget constraint in these countries outwards. But since public and private goods have the normal good property, in reaction to the outward shift of the budget constraint the countries outside the confederation reduce their contributions. Hence, only the member states of the confederation provide more public goods. Thus, we observe

$$(16) \qquad \frac{dG}{ds_1} > 0, \ \frac{dg_1}{ds_1} > 0, \text{ and } \frac{dg_2}{ds_1} < 0.$$

However, since all member states of the confederation increase their contributions, each of these countries benefit as long as the non-member states do not reduce their contributions too much. The degree of reduction of non-member states depends on the marginal propensity to consume because both an increase in income and higher contributions of

other countries yield to an outward shift of the budget constraint. The movement from point A to point B in figure 1 shows the effect of the subsidy on the non-member countries.[1]

Figure 1: How a subsidy in a confederation affects non-member countries

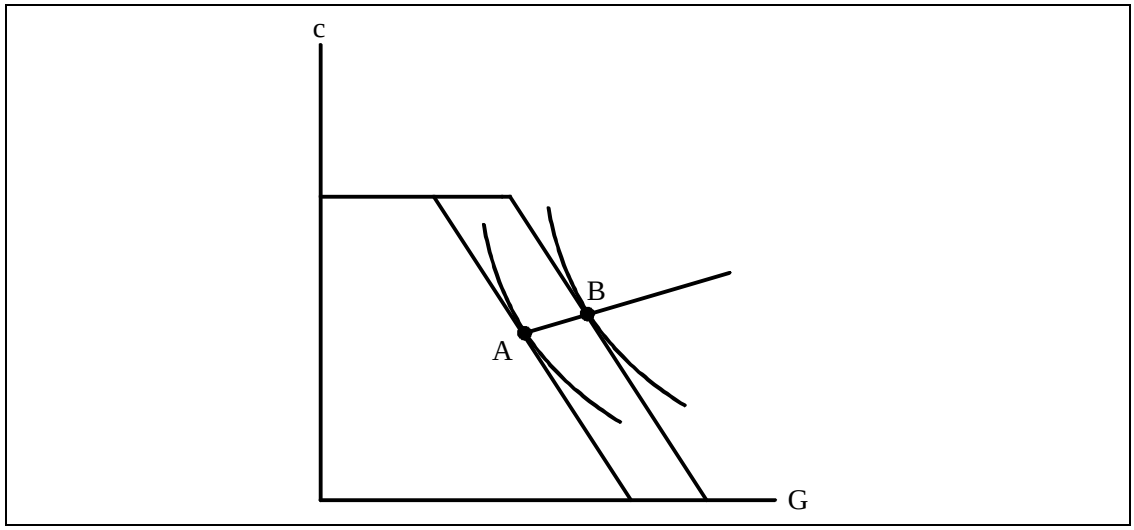
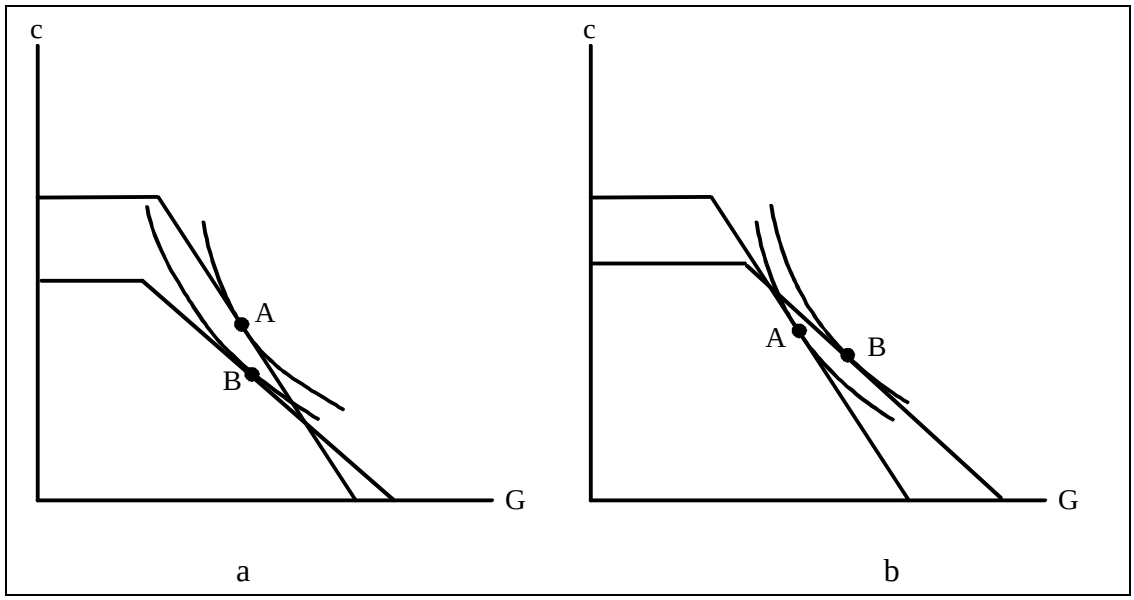


Figure 2 demonstrates the impact of the subsidy on a member state. The budget constraint is flatter if the subsidy is enacted. In figure 2.a welfare shrinks from A to B because non-member states reduce their contributions to a larger extent than member states increase them. Figure 2.b shows the opposite case. Member states benefit from the subsidy, too.

[1] This kind of picture has been used by Atkinson and Stiglitz (1980), p. 507.

Figure 2: The effect of introducing a subsidy in a confederation on member countries



Finally it is also of interest how the subsidy affects total welfare $W = n_1 U^1 + n_2 U^2$, in particular, if the condition of the proposition is not fulfilled. Summarizing the effects on countries' welfare, yields

$$(17) \qquad \frac{dW}{ds_1} = \frac{n_1(n_1 + n_2 - 1)p_1 q_1 q_2 G_U^2 G_q^2}{\Delta} + \frac{n_1 n_2 p_1}{\Delta}\left[q_2 E_U^1 G_q^1 - q_1 E_U^2 G_q^2\right].$$

While the first term is positive, the sign of the second term is ambiguous. However, in a symmetric situation, i.e. if the confederation and the rest of the world are equal, the terms in the square brackets cancel out, so that introducing a subsidy increases world-wide welfare. Moreover from the proposition follows that, if the marginal propensity to consume the public good is sufficiently large in the rest of the world, namely higher than approximately the share of the countries outside the federation in the total population, both countries benefit from the subsidy. Total welfare obviously rises. Otherwise, the total welfare effect is ambiguous.

IV. Environmental charges

An environmental charge levied by the confederation and to be paid by the countries can be considered as a subsidy on national effort to contribute to an international public

good. Suppose G is a public bad, with $g_1, g_2, G < 0$. The closer G to zero is, the higher is utility. The complete analysis can be adopted with only one minor change: The rate is s_1 and the revenue from the charge is redistributed in form of a lump-sum transfer T_1. The results can be stated as

Proposition 2*: Introducing an environmental charge on the contributions to an international public bad in a confederation of which revenue is redistributed in a lump-sum fashion, always increases welfare in the rest of the world, but also increases welfare in the member states if the marginal propensity to reduce consumption of the public bad is sufficiently large in the rest of the world, namely higher than approximately the share of the countries outside the federation in the total population.*

Using the analysis presented above, it is obvious that a environmental charge which has to be paid by a single country is harmful to this country. This particular case has been previously studied by Hoel (1991).

V. Concluding remarks

International public goods will be undersupplied as long as binding contracts are impossible. Unilateral introduction of environmental subsidies/charges by one country is harmful for the eco-pioneer. It is, however, not necessary to form a coalition which covers the whole number of countries affected by the public good. Smaller coalitions, namely federations or confederations, will benefit from subsiding contributions to public goods (from taxing contributions to public bads) if the marginal propensity to consume the public good (to reduce consumption of the public bad) is sufficiently large in the rest of the world, namely higher than approximately the share of the countries outside the federation in the total population.

Furthermore, there is theoretical evidence that larger coalitions are more likely to profit from subsidies/taxation.

The basic message of the model is that powerful and large coalitions such as the European union should seriously consider introducing environmental subsidies/taxes even if the underlying environmental problem is not restricted to Europe or if it is in fact

a global problem. The model suggests that taxes as environmental policy instruments to deal with global environmental problems ought to be not on the national but on the European agenda. Even global environmental problems are partially within the scope of European environmental policy. However, coalition policies are only imperfect substitutes for worldwide cooperation on the greenhouse effect and the hole in the ozone layer.

This analysis could also be applied to national environmental problems which could be dealt with by states, and to statewide pollution which can be partially solved by communities.

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