GLOBAL PUBLIC ECONOMICS: PUBLIC GOODS AND EXTERNALITIES*.

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Abstract.

This paper extends the normative analysis of public goods and externalities to an international setting. The first part considers the optimal allocation of a global public good. Whether global production efficiency is desirable depends on the existence of international lump sum transfers; in the absence of such transfers and with an egalitarian social welfare function a poor country should bear less of the burden of producing global public goods than implied by production efficiency. The second part of the paper analyzes global externalities and shows that internationally uniform Pigouvian taxation is only optimal in the presence of ideal lump sum transfers.

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GLOBAL PUBLIC ECONOMICS: PUBLIC GOODS AND EXTERNALITIES.

Some time ago, when I was in a process of writing an article on public goods[1] for the second edition of *The New Palgrave Dictionary of Economics*, I asked my editor whether there would be a separate entry on "Global public goods"; if not, I would like to include some material on this topic. He replied that there would not in fact be a separate article, and that I was welcome to go ahead with my plans. He then added that he had searched the electronic master list for all entries and was amazed to see how many authors had introduced their articles by using the word "global". Interestingly, however, it turned out that in all these cases "global" referred to analytical concepts like global curvature and global games, not to global economic issues in the sense that I am using the word here. Perhaps this is an indication that we economists - and public economists in particular - tend to pay too little attention to problems that concern the world as a whole, and it is with the hope of contributing to a more global perspective on our subject that I have chosen this topic for my presentation[2].

Global public goods is of course not an entirely neglected topic in the recent literature. E.g., there have recently come out two collections of articles (Kaul, Grunberg and Stern 1999 and Kaul, Conceicao, Le Goulven and Mendoza 2003) that look both at the theory, the empirical relevance and the implications for economic policy. Another sign that the interest in the field is increasing is the fact that it has been chosen as the theme of the 2007 Congress of the International Institute of Public Finance.

The theoretical basis.

The obvious starting point for any application of the theory of public goods is the original contribution by Paul Samuelson (1954, 1955). His classic papers contain few explicit references to the jurisdictional framework in which decisions about public goods provision are assumed to take place, but a natural interpretation is that he primarily had in mind the nation-state. However, it is also a reasonable assumption that he saw the theory as being applicable to several types of jurisdictional frameworks. Such applications in later years have mainly been in the area of local public goods and local public finance. Only recently has the attention of economists been turned to goods that are public in regard not only to the

[1] This article will be a revision and extension of Sandmo (1987).
[2] The text builds on and integrates material from two previous articles of mine (Sandmo, 2003, 2005).

population of a particular country, but with respect to the world population as a whole. The qualitative properties of the global environment offer perhaps the most obvious examples of such goods, but there are many others. Knowledge is an obvious and important example, while public health is another public good with important international dimensions. At the institutional level, important examples of global public goods are institutions required to promote world peace and international security or to sustain the global market economy.

The Samuelson formulation is cast in the framework of welfare economics. Starting from an individualistic welfare function, the aim of the analysis is to characterize an optimal allocation of resources when social welfare is maximized subject to a production possibility constraint. The most famous result to emerge from the analysis is the "Samuelson rule": The sum of the marginal rates of substitution, taken over all consumers in society, between the public good in question and some *numéraire* private good, must be equal to the marginal rate of transformation in production. An alternative interpretation is that the aggregate marginal willingness to pay for the public good must equal its marginal cost of production.

A central concern in the following discussion is the question of the validity of the Samuelson rule in a global context. Is this the way that we should think about the provision of global public goods? If not, what are the changes or modifications that need to be introduced before the theory can be applied to this type of public good? It will be shown that the most problematic part of the extension concerns the desirability of production efficiency and the separation of equity and efficiency conditions which plays such important roles in Samuelson's analysis.

Some of Samuelson's examples of pure public goods were "an outdoor circus or national defense" (Samuelson 1955). Apart from their tongue-in-cheek nature, these are examples where we are led to think of the goods being provided by explicit choice of some well-defined decision maker, but for many public goods this is a simplified picture. Whether we think of the natural or the cultural environment, it is clear that at any point in time these goods are partly determined by exogenous forces; they are given by the laws of nature or by human activities of the past. Their current and future availability is also determined by the actions of a large number of consumers and producers. The effects of these actions are sometimes negative, sometimes positive, and at least in the present context it is natural to think of externalities as *unintended effects of private actions on the availability of public goods*. There

is accordingly a close connection between the normative theories of public goods and externalities.

A model of resource allocation: Basic assumptions.

The notion of a social welfare function, so central to the Samuelson theory of public goods, is viewed by many with a good deal of scepticism. This stems partly from the Arrow impossibility theorem (Arrow 1951), partly from the criticism by Buchanan[3] and others of the public choice school that the very notion of an aggregate social welfare function is inconsistent with the values of a democratic society. Although the scepticism would seem to apply *a fortiori* to the notion of a global social welfare function, it will, nevertheless, be used below. I should stress, therefore, that my use of this concept does not in any way deny the force of the Arrow theorem. It is not meant to imply that there exists a political system of global preference aggregation, nor that there is a benevolent global planner who manages the world's resources according to his ethical values. The role of the social welfare function in the following is just to help us understand the limited significance of social efficiency or Pareto optimality as the sole guide to rational decisions. Thereby it also helps us to understand the dividing line between efficiency considerations on the one hand and ethical judgements on the other.

For simplicity, I assume that the world can be thought of as having two countries, one rich and one poor. The rich country consists of n consumers with utility functions u^{iR}, where $i=1,\ldots,n$. Similarly, the m consumers of the poor country have utility functions u^{jP}. For further simplicity I assume that there is just one private and one (global) public good, so that the utility functions can be written as

$$u^{iR} = u^{iR}(x^{iR}, g) \ \ (i = 1,\ldots,n), \text{ and } \ u^{jP} = u^{jP}(x^{jP}, g) \ (j = 1,\ldots,m). \qquad (1)$$

Here x^{iR} is the private good consumption of the i'th individual in the rich country, and x^{jP} has a corresponding interpretation. The global public good g enters into all utility functions, but the subjective valuations of the good may differ between individuals. It is likely to differ between

[3] A selection of Buchanan's writings in this area is in Buchanan (1987).

the average consumers in the rich and the poor country, and also within the populations of the two countries.

The public good, as it is modeled here, is a *pure public good* in the Samuelson sense. It is public both within and between the two countries. The enjoyment of the good by citizen *i* in country *R* does not diminish its availability for citizen *j* in country *P*. This type of public good is a polar case which allows us to focus on the problem of global public goods in its purest form. However, there are clearly a number of alternatives for theoretical modeling that have a higher claim to descriptive realism. Greenhouse gas emissions may have effects on global warming while at the same time causing air pollution in the country of origin; reducing domestic emissions may therefore simultaneously contribute to a global and a national public good. Moreover, since air pollution is mainly generated as a by-product of the consumption and production of private goods, it may also be treated as a case of private goods use with both national and international external effects. The present focus on pure public goods is motivated, first, by the desire to provide a direct extension of the Samuelson model to a global context, and, second, to study the problem of incentives in a setting directly comparable to the original formulation of the theory. The explicit analysis of externalities will be considered below.

The social welfare function is

$$W = W(u^{1R},\ldots u^{nR}; u^{1P},\ldots u^{mP}). \qquad (2)$$

Note that the maximum of the social welfare function (subject to the production possibilities constraint) is necessarily also a global Pareto optimum. For if we have an allocation where we can make one consumer, e.g. the poorest individual in the poor country, better off without making anyone else worse off, the value of the social welfare function must increase. Therefore, such an allocation cannot be a welfare maximum.

The description of the production side of the economy proceeds in two steps. On the one hand it is assumed that both countries devote some of their resources to provide the global public good, and that the global provision is an increasing function of the individual countries' contributions. In general, this can be written as

$$g = j(g^R, g^P). \qquad (3)$$

In the following I shall, for simplicity of exposition, use the more specific assumption that

$$g = g^R + g^P. \qquad (3')$$

The special assumption that the amount of global public good is equal to the sum of the individual countries' contributions is one that in this particular context must mainly be justified in terms of analytical simplicity, while it does not affect the nature of the conclusions. More generally, however, it is reasonable to assume that the different countries' contributions may have a different degree of efficiency in contributing to the global public good[4].

Each of the countries is constrained in its output of private and public goods by technology and factor supplies, and these constraints can be written as

$$F^R(x^R, g^R) = 0, \text{ and } F^P(x^P, g^P) = 0. \qquad (4)$$

Here x^R and x^P are the aggregate quantities of private goods produced and consumed in the rich and the poor country, respectively, so that $S_i x^{iR} = x^R$ and $S_j x^{jP} = x^P$.

Equations (4) give us, for each country, the maximum amount of contribution to the global public good that can be achieved for any given amount of private good consumption. Behind the efficiency frontier, which is assumed to have the usual concavity properties, lies a number of assumptions about the efficient allocation of factors of production among sub-sectors of the economy, but for reasons of space these will not be discussed explicitly here. In order to facilitate an intuitive interpretation of the results, in the following I will use the quasi-linear forms[5]

$$x^R + C^R(g^R) - ?^R = 0, \text{ and } \quad x^P + C^P(g^P) - ?^P = 0. \qquad (4')$$

[4] In theories of externalities and public goods several alternative assumptions have been explored concerning the relationship between individual contributions and the aggregate outcome, of which the case represented by (3') is clearly a special although important one. Cornes and Sandler (1996), who survey a number of alternative models, refer to the present case as that of a "summation technology".

[5] A similar form was used by Chichilnisky and Heal (1994).

Here $?^R$ and $?^P$ are constants representing the resource limitations of the two economies. The functions C^R and C^P are assumed to be continuous with positive first and second derivatives. This ensures that the production possibility curves have the usual properties. Moreover, the marginal rates of transformation, which in general should be written as F^R_g/F^R_x and F^P_g/F^P_x now become simply C^R_g and C^P_g. (Here and elsewhere subscripts will be used to denote partial derivatives in a notation that should otherwise be self-explanatory.) The latter expressions have an obvious interpretation as the marginal cost of producing the public good in terms of the quantity of private goods foregone.

Formally, the main difference between the present formulation and the standard one lies in the disaggregated treatment of the production side. It is obviously reasonable to assume that factor supplies and technologies differ between rich and poor countries, and even more reason than in a single-country analysis to be explicit about the conditions for productive efficiency.

Production efficiency.

As a step towards solving the global welfare maximization problem it is accordingly useful to examine the more limited issue of world production efficiency. A global allocation of resources in this context can be said to be productively efficient if, for some given total of the world's consumption of private goods, the provision of the global public good is at its maximum. This might seem to be desirable in view of the wider objective of global welfare maximization, for in the absence of production efficiency it would have been possible to reallocate the world's resources so as to have more of the public good without suffering a loss of private goods output. Such a reallocation would have the potential to improve the standard of living for all.

Formally, the problem of characterizing production efficiency can be written as

$$\textit{Maximize } g \textit{ subject to } x^R + x^P = x^0, \qquad (5)$$

where x^0 is some given amount of world output or consumption of the private good. Using equations (4'), production efficiency can be characterized by these and the condition

$$C^R_g = C^P_g. \qquad (6)$$

This condition says simply that for global production efficiency to hold, the marginal cost of public goods must be the same in rich and poor countries. In other words, comparative advantage should be fully exploited. The country in which factor endowments and technology make it cheaper to produce the public good, should devote more resources to it.

The flavour of the production efficiency result is strongly reminiscent of a classic insight from the Heckscher-Ohlin version of the theory of international trade, where the exploitation of comparative advantage assures global production efficiency[6]. In that theory the next step is to show that free international trade will establish relative producer prices that are uniform across countries. Since, in a competitive equilibrium, these will be equated to the marginal rate of substitution in each country, it follows that free trade will result in an efficient allocation of production between countries. But international trade theory is almost exclusively about trade in private goods. It is interesting to ask under what institutional conditions a similar result can be expected to emerge in the context of public goods, and this will be considered further below.

Is global production efficiency necessarily desirable? Welfare economics has taught us to think that production efficiency is necessary for social welfare maximization; if some outputs can be increased with no decrease of other outputs, it must be possible to make it better for some consumers without making it worse for others. But in an international context it is not clear that this argument can be applied. Our interest in the efficiency problem (5) must ultimately derive from the assumption that the whole of world output of the private good is available to satisfy consumer needs in both countries; if, instead, national consumption possibilities are constrained by national output, the present formulation of the problem loses much of its appeal. These issues can only be clarified by embedding the production efficiency problem in the wider framework of welfare maximization.

Global welfare maximization.

[6] This must be understood as relative to the assumption that factors of production are internationally immobile.

We now consider the more general problem of global welfare maximization. This will be conceived as the maximization of the social welfare function (2) subject to the technological constraints (3') and (4'). In addition, we need to specify the connection between world consumption and world production. To begin with, we assume simply that world consumption must equal world production, so that

$$S_i x^{iR} + S_j x^{jP} = x^R + x^P. \qquad (7)$$

Solving this problem of constrained optimization we obtain the following three sets of optimum conditions:

$$C^R_g = C^P_g \circ C_g. \qquad (8)$$

$$S_i(u^{iR}_g / u^{iR}_x) + S_j(u^{jP}_g / u^{jP}_x) = C_g . \qquad (9)$$

$$W_{iR}\, u^{iR}_x = W_{jP}\, u^{jP}_x. \qquad (i=1,....,n;\ j=1,....,m) \qquad (10)$$

Equation (8) is the condition for global production efficiency (6), restated here for convenience. This condition ensures that the marginal cost of the public good - the opportunity cost of public goods provision in terms of private goods output - is the same in both countries, and this common value will be written as C_g. Equation (9) is a direct generalization of the Samuelson efficiency condition for public goods: The sum of the marginal rates of substitution between the public and private good - the sum of the corresponding sums for each of the countries - should be equal to the global marginal rate of transformation. Another way to write this condition is as the requirement that the marginal benefit-cost ratio - the ratio of marginal benefits to marginal costs - should be equal to unity, i.e.

$$[S_i(u^{iR}_g / u^{iR}_x) + S_j(u^{jP}_g / u^{jP}_x)] / C_g = 1. \qquad (9')$$

Finally, the set of equations (10) is a requirement that the social marginal utility of private goods consumption be the same both for all consumers in each of the countries *and* across countries. Together, (8)-(10) constitute a complete characterization of the conditions for an

optimal world allocation of resources. While conditions (8) and (9) are characterizations of efficiency or Pareto optimality, equations (10) characterize the just or equitable distribution of resources between individuals.

At this point the generalization of the Samuelson analysis to an international setting may seem straightforward. In particular, the condition for optimal provision of public goods has the same form as in the original model, except for the splitting up of the sum on the left-hand side into one sum for each country. At the level of utopian thinking about world welfare, this may not be very surprising. However, as indicated above, the results are based on the assumption that private goods consumption in each of the two countries is only constrained by world output, not by the level of output in the country itself. This may be too utopian to be helpful. It is true that international trade allows countries to choose consumption patterns outside their sets of production possibilities, but the assumption here is stronger than that. Since the single private commodity x represents the aggregate of all private consumption goods, national consumption can only differ from national production in the case where there exist transfers of consumption or income between countries, and it is this feature of the analysis that leads to the equity conditions (10). In other words, the constraint (7) is equivalent to an assumption of lump sum transfers not only within each country but also between countries, and it is this assumption that allows the neat separation of efficiency and equity considerations in the optimal solution. This is exactly similar to the Samuelson analysis. Implicit in the formulation is also the requirement that the net revenue from the transfers must be positive and equal to the resource cost of public goods provision.

Transfers of this kind should not be ruled out as irrelevant and uninteresting. The amount of foreign aid and development assistance is significant and could be increased further; moreover, as will be discussed further below, some transfers could be seen as payments for public goods supply. Nevertheless, it is also true that most countries in the main have to rely on their own resources, and it is therefore of obvious interest to examine the case where consumption in each of the two countries is constrained by its own output. This assumption can be represented by the two constraints

$$S_i x^{iR} = x^R, \;\; S_j x^{jP} = x^P, \qquad (11)$$

and these should be compared with the single condition (7) for the previous case. It must be emphasized that (11) does *not* imply that there is no international trade. With the interpretation of the single private good as an aggregate of all goods, the meaning of conditions (11) is therefore that the value of production must be equal to the value of consumption; in other words, trade must be balanced. By contrast, assumption (7) allows for the value of consumption in a single country to be either higher or lower than the value of production, and this can only happen through international transfers. Thus, both (7) and (11) are consistent with an assumption of free trade; the difference between them is that (11) rules out international transfers.[7]

How does this change of assumption affect the case for production efficiency? First of all, it is worth emphasizing that the welfare case for *national* production efficiency remains valid. If one assumes the possibility of national lump-sum redistribution of income, it follows directly that the output of the private good should be maximized for any given level of public good contribution. In other words, national welfare can always be improved by moving from inside the production possibility frontier to some point on it.[8] On the other hand, *global production efficiency is in general not desirable.* It is easy to see why. Assume that the two countries are initially in a situation where the marginal cost of the public good differs between them. Suppose that it is found that the concern for global production efficiency calls for the poor country to contribute more to the public good and for the rich country to contribute less. The poor country must then move along its production possibility frontier in the direction of less production of the private good, while the rich country will produce more. On average then, the poor country consumers must get less private goods consumption and the rich country consumers must get more. This will involve a welfare loss, on the average, for consumers in the poor country, and a corresponding gain to the rich country consumers. If the latter could transfer some of their gains to the former, everyone could gain, but it is precisely the inability to make these transfers that is implied by assumption (11).

Formally, the condition for optimal supply of public goods in this case can be written as

$$S_i(u^{iR}_g / u^{iR}_x)/C^R_g + S_j(u^{jP}_g / u^{jP}_x)/C^P_g = 1. \qquad (12)$$

[7] The formulation is similar to that in models of international trade with one traded and one non-traded good; for an exposition see e.g. Bruce and Purvis (1985), pp. 814-817.
[8] Indeed, Diamond and Mirrlees (1971) showed that under certain conditions the case for production efficiency remains valid even when the only instruments for redistribution are distortionary taxes.

This equation should be compared with the corresponding equation (9') for the case when international transfers are possible; this says that the optimal provision of the global public good implies that the marginal benefit-cost ratio for the world as a whole must equal one. By contrast, (12) says that without transfers, it is *the sum of the national marginal benefit-cost ratios* that should equal one.[9]

While (9') represents an obvious extension of the theory of public goods to a global context, the interpretation of (12) is less obvious. A country's preferences for the global public good should count for more in the evaluation of global benefits, the lower is its marginal cost of producing the good; in this way, the aggregation of preferences across countries takes some account of production efficiency, which is intuitively reasonable.

But a puzzling feature of condition (12) is the apparent absence of welfare weights. Since there is no equalization of the social marginal utility of consumption between the rich and poor countries, one would expect the benefits to be weighted by terms that reflect the distributional preferences embedded in the social welfare function. Recall that we have assumed that there are perfect lump-sum transfers within but not between countries[10]. Consequently, the social marginal utility of consumption will be the same for all consumers in the poor country, and also between all consumers of the rich society. Formally, this can be written as

$$W_{iR}\, u^{iR}{}_x = g^R,\;\; W_{jP}\, u^{jP}{}_x = g^P, \qquad (i=1,....,n;\; j=1,....,m) \qquad (13)$$

where g^R and g^P are the common social marginal utility of income for each of the two countries. From (12) the *relative* weight on the poor country's preferences is $C^R{}_g \,/\, C^P{}_g$ **.** But from the solution to the optimization problem it can be shown that this is in fact equal to g^P/g^R, so that (12) has an alternative interpretation in terms of welfare weights. If the global welfare function has an egalitarian form, $g^P/g^R > 1$, and more weight is attached to the preferences of the poor population in deciding on the optimal provision of the global public good.

[9] The derivation of equation (12) is shown in Sandmo (2003).
[10] This is obviously not a realistic assumption. Its use here should be seen as an attempt to capture the idea that national redistribution policy is more highly developed than redistribution between countries.

The connection between cost weights and welfare weights has an intuitive economic explanation. If the social welfare function has an egalitarian bias, so that more weight is attached to private goods consumption in the poor country, one would like it to contribute less to the global public good. But since the marginal cost of providing the public good is increasing, this implies that the marginal cost in the poor country must, in an egalitarian optimum, be low compared to that of the rich country. The poor country should therefore devote less resources to global public goods than indicated by considerations of comparative advantage.

An interesting question is whether the optimum without international transfers would entail a higher or lower solution value for the public good than the optimum solution when such transfers are possible. However, at the purely 'technological' level, abstracting from all incentive problems, no firm answer to this question can be given. Intuitively, whether a greater weight on the benefits derived by the poor country will increase or decrease the sum of marginal benefit-cost ratios, depends on whether the poor country's benefits are high or low compared to that of the rich country.

A natural extension of the present analysis would be to the case where countries must finance their expenditure on global public goods through distortionary taxes. In that case, countries' comparative advantage in the production of global public goods would be based not only on differences in marginal production costs but also on differences in the efficiency of their tax systems. However, such an extension of the literature on the marginal cost of public funds to an international context lies beyond the scope of the present paper and must be left for future research.

Global externalities.

A theoretical insight that was first clearly formulated by Pigou (1920) is that market failure which is due to negative environmental externalities can be ameliorated by an appropriately designed tax system whereby polluters are confronted with a tax that leads them to internalize the social effects of their own actions. When all polluters are faced with the same tax rate the system will not only lead to an efficient balancing of costs and consumption benefits, but also to production efficiency in the sense that the reduction in emissions is achieved at a minimum of social costs. Although an efficient allocation can also be achieved through alternative

allocation systems, in particular by a system of transferable quotas, Pigouvian taxes will serve well as an illustration of the issues involved in extending the principles of environmental policy to an international setting. The importance of this particular application of the theory is underlined by recent concerns about the emission of greenhouse gases and its effects on global warming[11].

The analytical model will in essence be the same as before; thus, we will continue to assume that there exist perfect redistributive transfers within each of the countries. The main change is that we have to assume that there are two private goods instead of just one; without this extension we cannot handle the issue of relative price changes. As before, there will be one public good which now is in the nature of a "bad", viz. global environmental pollution, *e*. The utility functions can then be written as

$$u^{iR} = u^{iR}(x^{iR}_0, x^{iR}_1, e) \ (i=1,....,n) \ \text{and} \ u^{jP} = u^{jP}(x^{jP}_0, x^{jP}_1, e) \ (j=1,....,m). \qquad (14)$$

Pollution is generated by the global output of commodity *1* according to the simple relationship

$$e = x^R_1 + x^P_1, \qquad (15)$$

where x^R_1 and x^P_1 denote volumes of production in the two countries. This formulation corresponds to equation (3') in the public goods case. The production constraints take the same quasi-linear form as above:

$$x^R_0 + C^R(x^R_1) - ?^R = 0, \ \text{and} \ x^P_0 + C^P(x^P_1) - ?^P = 0. \qquad (16)$$

In a competitive equilibrium in each of the two countries, taking commodity *0* as the *numéraire*, consumers will equate their "private" marginal rates of substitution (i.e., taking the state of the environment as given) to the consumer price of commodity *1* (*Q*), while producers will set their marginal cost equal to the producer price (*q*)

$$u^{iR}_1 / u^{iR}_0 = Q^R, \qquad (i=1,....,n) \qquad (17a)$$

[11] For a recent survey of the main policy issues see Goulder and Pizer (2006).

$$C^R_1(y^R_1)=q^R. \qquad (18a)$$

$$u^{jP}_1/\,u^{jP}_0=Q^P, \qquad (j=1,....,m) \qquad (17b)$$

$$C^P_1(y^P_1)=q^P. \qquad (18b)$$

As before, there are two alternative sets of assumptions regarding the relationship between production and consumption. There is no need to spell these out in detail, since they correspond closely to the alternative assumptions (7) and (11). On the one hand the individual countries' consumption could be constrained only by world output; this corresponds to the case of lump sum international transfers. On the other hand, the consumption of each country could be constrained by the need for balanced trade. In the first case, the optimal Pigouvian tax will be the same in the rich and the poor country and be given by

$$t=[S_i(u^{iR}_e/\,u^{iR}_0)+S_j(u^{jP}_e/\,u^{jP}_0)]. \qquad (19)$$

This is essentially the formula for the optimal Pigouvian tax under first-best conditions (Sandmo 2000), where the sum of marginal benefits is taken over all consumers in the two countries. The tax induces the consumers to internalize the benefits to the world community as a whole of a marginal reduction in the consumption of the polluting commodity. It is therefore not surprising that the measure of social benefits is the same as the Samuelson measure of the benefits of public goods supply: A reduction in environmental pollution implies an improvement of the global environment, which is a public good.

Alternatively, we now assume that there are no international transfers. A global uniform tax will then no longer be optimal. The tax rates in the two countries will be given by[12]

$$t^R=[S_i(u^{iR}_e/\,u^{iR}_0)+S_j(u^{jP}_e/\,u^{jP}_0)(?^P/?^R)], \qquad (20)$$

and

[12] For the derivation of the optimal tax formulae see the Appendix to Sandmo (2005).

$$t^P = [S_i(u^{iR}{}_e / u^{iR}{}_0)\,)(?^R / ?^P) + S_j(u^{jP}{}_e / u^{jP}{}_0)], \qquad (21)$$

where the term $?^P / ?^R$ is the ratio of the social marginal utilities of income in the two countries. These are equal between individuals within each of the countries because of the assumption of domestic lump-sum redistribution; see equation (10) above. We assume the global welfare function to be egalitarian, so that the weight accorded to the marginal social damage for the rich country consumers will be less than that of the consumers in the poor country; this implies that $?^P / ?^R > 1$.

Comparing (20) with (21), we see immediately that

$$t^R = t^P(?^P / ?^R), \qquad (22)$$

which implies that $t^R > t^P$: The optimal tax in the rich country is higher than in the poor country. We may think of the ratio of welfare weights as expressing the degree of egalitarianism embedded in the global social welfare function. In the limit, as the ratio $?^R / ?^P$ approaches zero, giving lexicographic priority to the welfare of the poor country, the tax in the poor country goes to zero, and the whole burden of discouraging global pollution falls on the tax policy of the rich country[13].

Problems of implementation: The evaluation and revelation of benefits.

Suppose that the governments of each country have found a way to estimate national benefits from global public goods, including the global environment. This means that they have overcome the difficulties that stem from individuals' private incentives to misrepresent their benefits in order to avoid paying for public goods[14]. The next step is now to arrive at a measure of global benefits. If we envisage the governments of the world negotiating about an environmental treaty, each of them finds itself in a situation which in terms of strategic considerations is similar to that of a single individual with respect to the national government. Within the international community of nations most countries are small compared to the world as a whole. By underreporting its aggregate willingness to pay a country may

[13] Issues of efficiency in international taxation have been examined in Keen and Wildasin (2004), but their focus is not on externalities and corrective taxes.
[14] For surveys of methods of benefits assessment see Cropper and Oates (1992) or Sandmo (2000, ch. 4).

conceivable reduce the amount that it will actually have to contribute to the global public good without influencing the global provision of such goods appreciably. But if all countries reason along similar lines, the result will be under-provision of global public goods.

How serious is this international free rider problem? Again a crucial consideration is the availability of policy instruments for international redistribution. Consider first the condition (9') for optimal provision with unrestricted international transfers. If this condition is not satisfied, it is in principle possible to improve the situation for all countries through a combination of public goods adjustment and international transfers. One could envisage a system of international bargaining that would make it possible to convert a situation characterized by *potential* Pareto improvement to one of *actual* improvement, provided that the transfer mechanisms were sufficiently fine-tuned and flexible. This would not eliminate the incentive problems; individual countries might still find it in their own interest to report high costs and low benefits in order to increase their net gains from international transfers. Still, the combination of contributions to global public goods provision and income transfers would increase the possibility of achieving a global optimum, compared to the case with no transfers.

The latter case can be understood by considering condition (12), which generalizes easily to an arbitrary number of countries. In the absence of international transfers the marginal benefit-cost ratios should sum to unity. But this means that at the global optimum each individual country's ratio must be less than one. In other words, since a part of the benefits generated by the country in question accrues to other countries, all of them will be asked to contribute beyond the point where its marginal benefit-cost ratio equals one. Suppose that each country considers only its own welfare. If marginal benefit-cost ratios decline with the amount of public goods available, which is a reasonable assumption[15], no country would voluntarily use resources for global public goods beyond the point where its *national* benefit-cost ratio equals unity, but this would imply that the sum of these ratios would be of the order of the number of countries in the world, indicating a severe under-provision of global public goods.

[15] This follows if marginal benefits decline and marginal costs increase with the level of provision.

We must conclude, therefore, that whatever the difficulties are of achieving efficient and equitable provision of global public goods in combination with international transfers of income, the difficulties become magnified in the absence of such transfers[16].

Some modifications may be in order. The assumption that economic agents always take a narrow view of their own self-interest when considering the allocation of resources to public goods, is not hardly realistic. Even for single individuals in large economies we observe that people voluntarily donate time and money for the purpose of providing public goods. The increased concern for the environment in public policy has to a large extent been influenced by voluntary organizations that have been acting as pressure groups. Many individuals, obviously, do not see themselves as unable to influence aggregate outcomes like the allocation of resources to public goods or the design of policies to modify the effects of unregulated private actions. What is true for the single individual in the national economy is also likely to be true for a single country in the community of nations, particularly so since a number of countries are actually quite large relative to the world as a whole. One might therefore expect that, at least to some extent, they might be able to internalize the effects of their own actions on the state of the global environment[17].

Concluding remarks.

This paper has shown how the theories of public goods and externalities can be generalized to an international setting where countries contribute to the provision of global public goods or to environmental deterioration. At one level of discourse, the generalization is straightforward. Under the assumption of global welfare maximization the Samuelson optimality rule for public goods and the Pigouvian tax principles remain valid in a global setting. However, some of the assumptions required for the results to hold are distinctly less attractive in an international setting than is the case in the context of the nation state. The crucial one among these is the availability of individualized lump sum transfers. The political feasibility of such transfers is hardly a realistic option even within the context of the nation state, and in an international context it is even more doubtful. Nevertheless, this polar case is

[16] The combination of anti-pollution measures with international transfers has been discussed in a number of contributions to the literature on transfrontier pollution. For a theoretical analysis see Chander and Tulkens (1992). Mäler (1991) discusses the problem of practical implementation with numerical illustrations for the case of sulphur emissions in Europe.

[17] For a more detailed discussion of the incentive structures for global public goods provision, see Barrett (2001, 2003).

interesting in showing the precise conditions under which the standard optimality conditions are valid in an international context.

In order to demonstrate the crucial role of international transfers, we have assumed that, as an alternative, lump sum transfers are indeed feasible *within* the nation state, but that they are non-existent *between* states. In that case the optimality conditions are altered. First, global production efficiency is no longer desirable; in the interests of equity, poor countries might not be required to contribute as much to global public goods as their comparative advantage would otherwise call for. Second, the optimality condition for public goods provision changes to the requirement that the sum of the national marginal benefit-cost ratios should be equal to one. This condition brings to light an important incentive problem for the global economy, since each nation state finds itself in a strategic situation similar to that of the single individual in the nation state. To ensure the maximal gain to the world as a whole, each country must contribute to a point which, at least at the margin, involves a loss to itself. A similar insight holds for the case of externalities: In the absence of international lump sum transfers, with an egalitarian social welfare function the environmental benefits accruing to the consumers in the poor country should count more heavily in the assessment of global benefits. Also, the Pigouvian tax rate should be lower in the poor country than in the rich.

The two model alternatives - unrestricted lump sum international transfers versus no transfers at all - are obviously theoretical polar cases of international income redistribution. The more general conclusion that can be drawn from the analysis is that the incentive problem is easier to overcome when decisions concerning global public goods and externalities are combined with a policy of international transfers. Indeed, in the context of rich and poor countries, a policy whereby efficiency calls for extensive provision of global public goods by poor countries (e.g. preservation of the rain forest or of tropical bio-diversity) would be easier to implement if combined with a policy of redistribution. The transfers could in principle be designed in such a way that the overall gains from the provision of global public goods could be distributed among countries to ensure a positive gain for all.

An interesting perspective on transfers of this kind is to see them as payments for services rendered to the rich countries. The rich countries derive benefits from the poor countries' provision of global public goods (including environmental improvement), and if the poor countries do in fact have a comparative advantage in the production of such goods, the rich

countries can “buy” those goods cheaper abroad than at home. Thus, there are possible gains from trade here, but it must be kept in mind that to realize the gains one must somehow overcome the incentive problems that are inherent and inescapable in all problems of public goods allocation. Rich countries can obtain more worldwide bio-diversity - presumably a global public good - by paying poor countries to spend more resources on protecting endangered species. But a single rich country is nevertheless exposed to the free rider incentive to let other rich countries foot the bill.

For transfers of income to play the role envisaged here, they must be designed in a way that is rather different from current systems of foreign aid. Economists have sometimes argued in favour of non-conditional aid as the best way to overcome international inequality, and this would be consistent with the implications of the first version of our theoretical model. But in the context of a more restricted and practical role for income transfers, they ought rather to be designed so as to make them conditional on contributions to the provision of global public goods.

The main difference between public goods provision in the nation state and the global economy lies in the link with tax payments. Two differences of principle are of crucial importance. The first is that, in the nation state, a tax-financed increase in public goods could pass the benefit-cost test without providing gains to each and every citizen. This is because the nation state has instruments of enforcement by which it can extract payments also from those citizens who are not net beneficiaries from the policy, while the world community of sovereign nations does not possess policy instruments of this kind. In the global community participation in the policy must therefore be based on voluntary participation, so that it becomes important to develop policy tools that distribute the gains to all participating nations. The second difference lies in the possibilities of developing credible systems of enforcement. Even when all countries gain from the policies, individual countries would have an incentive to engage in various activities - such as misrepresentation of benefits or costs, evasion or avoidance of taxes or quotas - that would increase their net share of the global gains further. A viable system of global public goods provision must to some extent be based on countries' acceptance of a notion of global welfare that goes beyond national self-interest.

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