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Discussion paper

# The welfare economics of global public goods

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# **THE WELFARE ECONOMICS OF GLOBAL PUBLIC GOODS**

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## **Abstract**

This paper studies the conditions for a welfare-maximizing allocation of resources to the production of global public goods, such as biodiversity, the global climate, the cultural heritage, knowledge, and world peace. A global social welfare function is maximized subject to production constraints and alternative assumptions about the possibility of international transfers. It is shown that the desirability of global production efficiency is closely linked to the existence of international lump-sum transfers. Global public goods are considered both as consumption and production goods, and the theory is also applied to the issue of the uniformity of a global carbon tax.

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## 1. Introduction.

The increasing globalization of economic life has been accompanied by a globalization of the field of public finance, in the sense that the international aspects of the field have been receiving much more attention than they did before. The process began with an increasing interest in the area of international taxation, motivated by the liberalization of trade and factor movements that has been such a dominant feature of the development of the international economy over the last few decades. Only more recently has the expenditure or benefit side of the public finances been given similar attention, with global public goods being the central theoretical concept of a rapidly expanding literature.

What are global public goods? It is natural to approach this question by considering the standard definition of public goods, viz. that a public good is one whose use by one person does not reduce the amount that others can consume (Samuelson 1954). This is a very general definition which does not include a specification of the set of people to which it applies. Much of the literature has - sometimes implicitly - adopted the assumption that the definition applies to the population of the nation state, a popular example being national defence. But since the definition is essentially a technological one, it can be adapted to other institutional settings, and the first major application to develop after Samuelson's path-breaking 1954 paper was that of local public goods. The theory of global public goods represents the development of the theory in the opposite direction, focusing on goods that are public in the most general sense of the term: Their use by one person in the world does not reduce the amount that other persons in the world can consume.

Here are some examples of global public goods that have been discussed in the literature:

**Biodiversity and the natural environment.** Most of us enjoy the benefits from the natural environment in which we live or to which we have easy access. These benefits may be material, as when an unspoilt environment provides us with clean air and opportunities for physical exercise, but they are sometimes of a more intellectual or aesthetic nature. Moreover, benefits of the latter kind are not only derived from our immediate surroundings; we take pleasure in our knowledge of the natural majesty of the Himalayan Mountains and the wildlife of the Arctic, even if we personally have not and will never have the opportunity to observe Mount Everest or the life of the polar bear at close quarters.

**The global climate.** Global warming is a topic that has received enormous attention in recent years, with economists playing leading roles in the debate. The Stern Review (2007) has made us aware of the fact that the climate not only has strong elements of being a global public *consumption* good that yields immediate and future consumption benefits, but that it also is a public *production* good, affecting production possibilities in a number of different ways, not least for the world's poorest. The fact that an increase in the global temperature may yield positive benefits to some people and negative benefits to others is not inconsistent with the definition of the climate as a public good, since uniformity of benefits is not part of the definition of such goods.

**The cultural heritage.** The cities, buildings and other memorials of the past constitute a common cultural heritage that in principle can be enjoyed by all people in the world. This is recognized in UNESCO's concept of World Heritage sites, a list of properties deemed to be of outstanding universal value. UNESCO itself has clearly described the global public good nature of these properties as follows: "World Heritage sites belong to all the peoples of the world, irrespective of the territory on which they are located."<sup>1</sup>

**Knowledge.** New knowledge about the natural world, the functioning of society and mankind's artistic expression is produced every day and to a large extent becomes the common property of mankind. Clearly, people sometimes have strong incentives to prevent others from enjoying these common benefits by exploiting monopoly or patent positions, but at any rate knowledge is *potentially* a global public good.

**World peace.** That world peace, the absence of war and national insecurity with all that it implies for human welfare, is a global public good is hardly in need of supporting arguments. But the example is of particular interest in reminding us of the different perspectives that we have to take in thinking about national and global public goods. A leading example of a national public good is national defence. But military expenditure is not only used for defensive purposes; if that were true there would be no need for it. The case for devoting resources to military expenditure may be strong from the point of view of the nation's welfare but vanishing for the world as a whole.

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<sup>1</sup> The list of sites also includes places of exceptional natural beauty. For a further description of the 1972 World Heritage Treaty and the current list of properties see <http://whc.unesco.org/en/about/>.

A few general observations may be in order concerning these examples. From the viewpoint of public finance it is perhaps not obvious which items in the public budgets correspond to these goods. In some of the examples the public goods themselves are, at any point in time, determined by nature or by past history. But public expenditure, e.g. on the funding of national parks or the preservation of historic cities, will contribute to the quality of the public goods that we leave to posterity. It is typical of the examples that the public good itself is in the nature of a stock which has accumulated over time, and that current policies only determine flows that add to or subtract from the stocks. This has to be kept in mind when interpreting more formal models of allocation of resources to global public goods, which often abstract from these dynamic relationships.

Another point that needs to be kept in mind is that although the availability of a public good is the same for all, the individual valuation of it is likely to vary substantially (as in the case of global warming). One obvious reason for this is that tastes differ, but from a policy point of view it is just as important to realize that another reason lies in the enormous variations in opportunities that we observe in the global economy. For people living on minimal resources, the valuation of World Heritage sites in distant countries is likely to be zero not only because of the nature of their preferences, but also because of their lack of knowledge concerning these sites and of the resources needed to acquire the complementary private goods that are necessary to enjoy them, such as books, television sets and travel.

## **2. Some history of thought.**

Although the concepts of public goods in general and global public goods in particular are of relatively recent origin, their beginnings can be traced back to the classical writers in our subject. Thus, Adam Smith maintained that one of the central functions of a government was that of

“... erecting and maintaining those publick institutions and those publick works, which, though they may be in the highest degree advantageous to a great society, are, however, of such a nature that the profit could never repay the expence to any individual or small number of individuals.” (Smith 1776; 1976, p. 723)

The proposition that some goods yield public or collective benefits and that market incentives may for that reason be inadequate for an efficient provision of them, lies just below the surface of this formulation. However, the great society and the government which Smith had in mind were clearly related to the nation state. A large part of the *Wealth of Nations* may be read as advice to governments on the design of good policies, and Smith was a theorist with a practical orientation who did not concern himself with giving advice to a fictitious world government.

In the middle of the following century John Stuart Mill took a broader view of the tasks of government. After discussing the protection of private property as one of the central functions of the state he posed a rhetorical question to which he also gave a firm answer:

“But is there nothing recognised as property except what has been produced? Is there not the earth itself, its forests and waters, and all other natural riches, above and below the surface? These are the inheritance of the human race, and there must be regulations for the common enjoyment of it. What rights, and under what conditions, a person shall be allowed to exercise over any portion of this common inheritance, cannot be left undecided. No function of government is less optional than the regulation of these things, or more completely involved in the idea of civilized society.” (Mill 1848; 1965, p. 801.)

However, in reading this powerful statement, one wishes that Mill had pursued the issue further. The expression “inheritance of the human race” clearly indicates that there are some types of property that are common to more than the inhabitants of the nation state, and it is not made very clear how a national government can incorporate an effective concern for this inheritance in its own set of functions.

Although the beginnings of a formal theory of public goods provision can be found in the writings of Italian, German and Swedish economists of the 19<sup>th</sup> and early 20<sup>th</sup> centuries, the modern theory was founded in a short article by Paul Samuelson (1954; see also Samuelson 1955, 1958). Samuelson introduced a precise analytical definition of public goods as the case where total and individual consumption of a good are indistinguishable, and he formulated the theory in terms of welfare economics. The problem that he set out to solve was the characterization of the conditions for optimal resource allocation, optimality being defined in

terms of a Bergson-Samuelson social welfare function. Assuming that the economy was on its production efficiency frontier and that public expenditure, including spending on redistribution schemes, could be financed by individualized lump-sum taxes, he derived the famous “Samuelson rule” which says that the sum of the marginal rates of substitution between any pair of public and private goods should be equal to their marginal rate of transformation. The “rule” can also be derived without explicit use of the social welfare function as a subset of the conditions for Pareto optimality of a mixed private-public goods economy. But since any Pareto optimum corresponds to a particular set of (marginal) weights of a social welfare function, the two approaches really come to the same thing.

Samuelson did not commit himself to a specific definition of the set of people benefiting from the public good, although a natural interpretation is that he mainly had the nation state in mind. An important outgrowth of the theory was the study of local public goods, while the study of global goods took longer to develop. It was mentioned and clearly recognized by Olson (1971, p. 171), but in this area it is perhaps fair to say that the applications came before the general theory, since during the following decades, one can find a number of contributions which deal with topics that one would now define as examples of, if not global, at least multinational public goods. There was a considerable literature in the natural resource field that concerned itself with “the global commons”, and there emerged a literature on military and other trans-national alliances that had many features in common with the Samuelson theory of public goods<sup>2</sup>. Research on the economics of global public goods received a big push a few years ago when a group of researchers at the United Nations Development Programme (UNDP) made an effort to move the subject to the forefront of both the policy and academic discussion by bringing a number of economists together to discuss various aspects of the topic. This resulted in three books<sup>3</sup> that contain a number of interesting contributions and together constitute an important source of reference.

### **3. A global welfare maximum.**

It is possible to take the view that the extension of the theory of public goods from the national to the international level does not require much in the way of discussion and

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<sup>2</sup> See Sandler and Hartley (2001) for a survey of this literature.

<sup>3</sup> These are Kaul, Grunberg and Stern (1999), Kaul, Conceição, Le Goulven and Mendoza (2003) and Kaul and Conceição (2006).

reflection; all that is needed is a reinterpretation of the variables of the Samuelson model. I will argue that this attitude may be too superficial, and that a reconsideration of the various elements of that model makes us aware of some of the central difficulties in thinking about global public goods.

Not everyone is comfortable with the concept of a social welfare function, and if one is uneasy about it when applied to the national economy, then *a fortiori* there would seem to be every reason to be sceptical to its use on a global scale<sup>4</sup>. A way to avoid it is to focus on Pareto optimality, but an analysis of the production and consumption of global public goods that abstracts from distributional aspects becomes fairly artificial. Moreover, any allocation that represents an optimum relative to a Bergson-Samuelson social welfare function is necessarily also a Pareto optimum, so nothing is lost by taking the broader approach. Obviously, the analytical use of this type of function does not imply a belief in a global mastermind that allocates the world's resources. It simply helps us to understand the nature of the global trade-off between equity and efficiency for anyone whose view of the relationship between individual utility and social welfare can be represented by this class of social welfare functions.

For simplicity, I shall assume that the world consists of just two countries, one rich and one poor. There are  $n$  individuals in the rich country and  $m$  in the poor country. The global social welfare function can then be written as

$$(1) \quad W = W(u^{1R}, \dots, u^{nR}; u^{1P}, \dots, u^{mP}).$$

Note that this formulation does not assume that global social welfare is in some systematic way related to national welfare levels; instead it is assumed in general to depend directly on individual utilities. Letting global welfare depend on some notion of national "welfares" could be taken to imply a belief that such "welfares" exist as representations of official targets for national policy, and I do not wish to make such an assumption. One could argue that having  $W$  depend on some national welfare functions, say  $W^R$  and  $W^P$ , could simply be taken to reflect some arguably natural assumption about separability, but this is not really attractive. It would imply, loosely speaking, that our attitude to inequality in the rich country would be

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<sup>4</sup> An early statement of the need to take a global welfare view of the development of international economic institutions can be found in Frankel (1943).



independent of the standard of living of individuals in the poor country. While the formulation (1) admits this kind of assumption as a special case, as a general formulation it does not seem to capture what many of us would consider to be reasonable judgements about global inequality.

The arguments of the utility functions in (1) must in general be thought of as comprising several kinds of goods - pure private goods as well as local, national and global public goods. In the interests of simplicity I abstract from local and national public goods, and I also assume that there is just one global public good, while private goods are treated in terms of a single aggregate. This means that the utility functions can be written as

$$(2) \quad u^{iR} = u^{iR}(x^{iR}, G) \text{ and } u^{jP} = u^{jP}(x^{jP}, G). \quad (i = 1, \dots, n; j = 1, \dots, m)$$

Following the tradition established by Samuelson, I have modelled the global public good as a consumption good. This is of course a simplification. As the introductory examples showed, some of the most important classes of global public goods should also be thought of as production goods or public factors of production. An extension of the model in this direction will be considered in Section 5 below, but to begin with I choose to focus on the standard case of public goods as consumption goods. The basic issues that arise in the broadening of the perspective from the national to the global stage are in any case independent of this particular issue.

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 simply the sum of the individual countries' contribution:

$$(3) \quad G = g^R + g^P.$$

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

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

Here  $x^R$  and  $x^P$  are the aggregate quantities of private goods produced in the rich and the poor country, respectively. I shall refer to the marginal rate of transformation between the private and the public good as the marginal cost of producing the public good.

Formally, the main difference between the present formulation and the standard one lies in the disaggregated treatment of the production side. In the original Samuelson model the economy was assumed to be on its production possibility frontier; in other words, factors of production were assumed to be efficiently allocated between sectors of the economy. In the present context this would amount to assuming that the world as a whole is on its production possibility frontier. It is not natural to introduce this in the form of an *assumption* in the present setting, although we should naturally expect it to emerge as a possible *result* of global welfare maximization.

It now remains to specify the connection between world consumption and production of the private good, and here I will explore the consequences of two alternative assumptions. The first, on which I will concentrate in the following, can be written as

$$(5) \quad \sum_i x^{iR} + \sum_j x^{jP} = x^R + x^P.$$

This equation may look innocuous, but in fact it has rather far-reaching consequences. It implies that each country's consumption is constrained by world production, so that it is perfectly possible for a country to consume more than it produces. Note also that the assumption applies to an aggregate of all private goods, so that it does not simply represent the case of an open economy which consumes at a point outside its production frontier; instead it implies that the value of consumption may exceed the value of production. This can only be the case if there exist international transfers, so that e.g. there is a net positive volume of transfer payments from the rich to the poor country. This is obviously a very significant assumption to make about the global economy.

Given these elements of the model we may proceed to study the optimality conditions. I will skip all derivations and simply state the results. First of all, the allocation of resources must satisfy the condition for global production efficiency, so that the marginal cost of producing the public good should be the same in both countries. This result can be written as

$$(6) \quad MC^R = MC^P \equiv MC,$$

where the last term simply denotes the common value of the marginal cost. Whatever amount of the global public good it is desirable to produce, production should be carried out at the lowest possible cost, defined in terms of the amount of foregone consumption of the private good for the world as a whole.

How much of the public good should be produced? This is determined by the Samuelson rule, which it is convenient to write as

$$(7) \quad \sum_i MRS^{iR} + \sum_j MRS^{jP} = MC, \text{ or } \sum_i MRS^{iR}/MC + \sum_j MRS^{jP}/MC = 1.$$

The aggregate marginal willingness to pay - the sum of the marginal rates of substitution over all individuals in the global economy - should be equal to the common marginal cost; this is equivalent to the statement that the marginal benefit-cost ratio for the world as a whole equals one. Note that each person's marginal willingness to pay carries the same weight, irrespective of whether national or international differences among individuals are due to tastes or resources. Together, (6) and (7) constitute the conditions for a Pareto optimum of the world economy.

The final set of optimality conditions requires that the social marginal utility of consumption is the same for all individuals

$$(8) \quad SMU^{iR} = SMU^{jP} \quad (i=1, \dots, n; j=1, \dots, m)$$

Here the *SMU* stands for the marginal welfare effect of an increased consumption of the private good; the equality of these across individuals and countries is the condition for a just distribution of resources among individuals. Here "just" is to be understood in terms of the ethical judgments expressed by the marginal weights attached to the individual utilities in the social welfare function. Equations (6)-(8) constitute the complete characterization of an optimal world allocation of private and public goods.

#### 4. Constraints on international redistribution.

It is well known that the policy instruments that are necessary for bringing about conditions (8) consist of a set of individualized lump sum transfers that do not interfere with the efficiency of the economic system. The model as presented here is of course highly stylized, but if it were to be generalized to accommodate several commodities and factors of production, the requirement would be that transfers should not distort relative prices, and this implies that both commodity and income taxes must be ruled out. Note that these transfers must occur both between individuals in each of the two countries and in the world as a whole. We have to think of the world income distribution as being optimal, not simply the income distributions in the two countries taken separately.

We know from the general theory of the second best that if one set of optimality conditions does not hold, then in general the remaining conditions have to be modified also. The second best issue that I wish to focus on here is the following: What happens to the conditions for Pareto optimality (6)-(7) if the conditions (8) for optimal income distribution cannot be satisfied? A realistic view might be that the distributive conditions are unlikely to be satisfied, neither within each of the two countries nor for the world as a whole, but I wish here to focus on the international dimension. The extent of redistribution is certainly much larger within a single country than between the rich and the poor countries of the world. We represent this by the extreme assumption that while there are perfect redistributive transfers *within* countries, there are no transfers whatever *between* countries<sup>5</sup>.

Analytically, in the absence of international transfers, each country's consumption of private goods must be limited to its own output. Equation (5) has therefore to be replaced by the pair of conditions

$$(9) \quad \sum_i x^{iR} = x^R, \quad \sum_j x^{jP} = x^P.$$

In this artificial one-commodity model, where the single private good represents an aggregate of all private consumer goods and factor inputs, it is worth pointing out that assumption (9) does not rule out international trade. Instead, the two conditions may be taken to represent the balance of payments constraints in the absence of international transfers, in particular

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<sup>5</sup> Economics has of course a long tradition of theorizing in terms of extreme or polar cases. The distinction between private and public goods is itself an example of this. Another example, which is more closely related to the present discussion is the Ricardian assumption of perfect domestic factor mobility coupled with zero international mobility.

transfers from the rich to the poor country. In equation (5), by contrast, the value of a country's consumption was allowed to differ from the value of its production, precisely because of the existence of such transfers.

With the new assumptions, what happens to the production efficiency result and the optimality condition for global public goods? First of all, the availability of transfers in the national context means that there will be a common value of the social marginal utility of consumption within each of the two countries; call these  $SMU^R$  and  $SMU^P$ . Given that the levels of private consumption are lower in the poor country, and on the assumption that the social welfare function exhibits inequality aversion, we will have that  $SMU^R < SMU^P$ . When this holds, it follows that

$$(10) \quad MC^R > MC^P.$$

If marginal costs or marginal rates of transformation are increasing, it follows that the rich country should devote more resources to producing the global public good than called for by pure production efficiency. Starting from the production efficiency benchmark, transferring some public good production to the rich country would increase the resources available for private goods production in the poor country, and a move in this direction would increase world welfare. While global production efficiency is a desirable property of an unconstrained global optimum, this is no longer the case when international redistribution is no longer a feasible option<sup>6</sup>.

The cost-benefit rule for public goods provision becomes

$$(11) \quad \sum_i MRS^{iR}/MC^R + \sum_j MRS^{jP}/MC^P = 1,$$

and this should be compared with (7). Instead of the first best requirement that the global marginal benefit-cost ratio should equal one, this condition says that it is the *sum* of the national benefit-cost ratios which, at the optimum, should be equal to unity.

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<sup>6</sup> A similar result would obviously hold for less stringent constraints on international redistribution. As the scope for international redistribution increases, one would expect the optimum to move closer to the first best case of global production efficiency.

An obvious implication of either of the two versions of the global Samuelson rule is that optimality requires each of the countries to have a national benefit-cost ratio which is less than one; in other words, they must push production of the public good to a point where the domestic marginal cost exceeds the domestic marginal benefit. This feature of the optimum raises serious questions about national incentives in regard to global welfare, and I will come back to these later.

## 5. The global public good as a factor of production.

It is not obvious that we ought to think about global public goods as consumption goods. In fact, when we go back to reconsider the introductory examples, it is easy to see that all of them can also be interpreted as production goods or factors of production. Think of the natural environment and the global climate in relation to agriculture and fisheries, knowledge in relation to industrial development, or world peace in relation to almost any economic activity except armaments, and it is obvious that the major types of global public goods confer both consumption and production benefits on society. If we were to model the benefits of a specific public good like the development of a drug to prevent cancer, we ought clearly to include both consumption and production benefits. Here I would simply like to indicate briefly how to model the case of pure production benefits, leaving the mixed cases aside.

We now leave out the public good from the utility functions of the consumers, instead introducing it in the production constraints, which can be written as

$$(12) \quad F^R(x^R, g^R, G) = 0, \text{ and } F^P(x^P, g^P, G) = 0.$$

The functions  $F^R$  and  $F^P$ , while increasing in the first two arguments, are decreasing in  $G$ . This normalization assumption serves to capture the role of the public good as an input factor that expands production possibilities in each of the two countries. Since I am using the private good as the *numéraire* commodity, it will be convenient to measure this effect in each of the countries by the increased output of the private good which is made possible by an increased supply of the global public good. This is of course the marginal rate of transformation between the two goods, but to convey the economics more clearly, I shall refer to it as the *marginal output effect* (MOE) of the global public good. In the first best case, i.e. where

perfect international transfers are allowed, the optimal world allocation of the production of the global public good is characterized by the condition

$$(13) \quad MC^R = MC^P \equiv MC,$$

which is identical to equation (6) above: The optimal pattern of the production of public goods across countries is that which minimizes the resource cost for the world as a whole. To find the optimal scale of production we need to equate the common marginal cost to the world benefit, which is the effect on production possibilities for the world as a whole. Formally, this optimality condition can be written as

$$(14) \quad MOE^R + MOE^P = MC.$$

The common marginal cost should be equal to the marginal global benefit, which is the sum of marginal output effects across countries. Because I have treated the domestic production constraint as an aggregate (assuming domestic production efficiency), there is a difference in the treatment of consumption and production benefits as regards the explicit aggregation of benefits over domestic agents, but the basic notion of marginal domestic benefits from the global public good is fundamentally the same.

I refrain from presenting further details about the global public good as a factor of production. But it may be useful to point out that the case with no international redistribution gives rise to similar modifications as in the consumption case. Marginal costs of production should be higher in the rich country, which, in the interests of equity, should devote more resources for the global benefit. Moreover, condition (14) for the optimal scale of production should be modified to look formally similar to equation (11), implying a relatively greater weight on the production benefit that accrues to the poor country.

## **6. Externalities: The carbon tax.**

”... the weather is clearly an exogenous or non-economic variable, affecting individual choices but unaffected by them.” (Graaff 1957, p. 6.)

“Rainfall affects the economy but is not affected by the economy.” (Klein 1962, p. 16.)

These quotations are interesting illustrations of the fact that, fifty years ago, even the world's top economists were unaware of a connection that immediately comes to people's minds today as they are introduced to the concept of global public goods. At present it must be taken as established beyond any reasonable doubt that greenhouse gas emissions contribute to global warming, and that the emissions of any one consumer or firm create negative environmental externalities for individuals and firms all over the world. Although the discussion so far has been limited to the production and consumption of public goods in the more specific sense of the word, there is clearly a close connection between public goods and externalities. Indeed, externalities can be seen as the results of actions that indirectly affect the availability of public goods. The quality of the public good - the global climate, in this case - is determined by the aggregate outcome of billions of individual decisions regarding the technology of production in firms and households, modes of transportation and travel patterns, residential location and a number of other characteristics of modern economic life.

Economists have a long tradition of diagnosis and policy recommendation in this area. The standard recommendation is the use of Pigouvian taxes on harmful activities. The tax should be set at a level that reflects the marginal social damage of the activity, which is measured by the sum of the marginal rates of substitution between the quality of the environment and private consumption<sup>7</sup>. This is of course the public good component of the private activity, i.e. its negative contribution to the availability of the public good in question. A uniform tax on all polluters has the property that the marginal cost of reducing pollution - or the marginal cost of contributing to the production of the public good - will be equalized across polluters, thus ensuring production efficiency in environmental policy. The ideal Pigouvian tax will therefore lead to a social optimum characterized both by production efficiency and by an optimal balancing of the benefits and costs of environmental policy. Applied to the specific case of CO<sub>2</sub> emissions, the optimal carbon tax should be globally uniform, a recommendation also strongly emphasized in the Stern Review (2007).

However, it must be kept in mind that this is a characterization of the first best, where there are no constraints on the use of policy instruments; in particular, lump sum transfers are

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<sup>7</sup> A demonstration of this result and further elaboration of the connection between environmental externalities and public goods can be found in Sandmo (2000).



included in the set of feasible policies<sup>8</sup>. If we accept the lack of realism involved in this assumption, we must consider the modifications with respect to tax policy that need to be introduced if the problem of efficient allocation cannot be separated from that of an equitable distribution of income.

The result follows almost immediately from those derived in the previous section. If lump sum international transfers are infeasible or inadequate, and if the global social welfare function is egalitarian, the tax in the poor country should be lower than in the rich. This means that the marginal cost of contributing to the global public good should be lower in the poor country, which allows it to devote more of its resources to the production of private goods. Lowering the tax that it has to pay is a way - in fact, under the assumptions made, the only way - to transfer income from the rich country. This has a cost in the form of global production inefficiency, but a global social welfare function that gives some weight to international equality implies that it is rational to pay a cost for a more equitable distribution of the cost of climate policy<sup>9</sup>.

## **7. Incentives and implementation.**

Suppose, for the sake of the argument, that all governments have found a way to estimate *national* benefits from global public goods, including the global environment. This is obviously a drastic simplification, implying that the countries have overcome the difficulties associated with eliciting true preferences for public goods. Once again, however, the justification is that the simplification allows us to focus on the international dimension. 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, the objectives of the treaty would be first, to decide on the amount of the public good to be produced and second, to agree on a division of the cost of production among the parties to the agreement. It is natural to assume that during the process of negotiation the representatives of each country know their own country's benefits and costs, but that these are not known - or at least less well known - to the negotiators of other countries.

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<sup>8</sup> The Stern Review (2007, p. 364) remarks, after arguing the case for a uniform carbon tax, that "an additional mechanism would need to be put in place to transfer resources to developing countries."

<sup>9</sup> In order to move the analysis closer to real world policy issues we must consider the implications of this result for a world of many countries. Country-specific tax rates may be politically difficult, and an alternative might be a small number of tax rates, each applying to a group of countries. For further discussions of this see Sandmo (2005).

Each country then 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 overrepresenting its marginal costs or underrepresenting its marginal willingness to pay for the global public good a country may conceivably reduce the amount of resources that it will actually have to contribute without, in its own view, influencing the global provision of such goods appreciably. But if all countries reason along similar lines, the result will be underprovision of global public goods - a standard result in the theory of 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 (7) 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 Wicksell-Lindahl 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 (11), 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 their domestic 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<sup>10</sup>, no

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<sup>10</sup> This follows if marginal benefits decline and marginal costs increase with the level of provision.

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, instead of being equal to unity, would be of the order of the number of countries in the world, indicating a severe underprovision of global public goods.

When provision of global public goods is combined with international transfers, one can imagine a system of international bargaining whereby the rich country offers transfers in return for increased production in the poor country, assuming that marginal costs of production are lower there. The outcome of such a bargaining process could be envisaged as an international Lindahl equilibrium of production and transfers, with countries playing the role of individuals in the standard Lindahl model (Johansen (1963)). We must conclude, therefore, that the possibility of achieving efficient and equitable provision of global public goods is significantly larger in the presence of international transfers of income than in the situation where such transfers are non-existent<sup>11</sup>.

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 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<sup>12</sup>.

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<sup>11</sup> 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). Måler (1991) discusses the problem of practical implementation with numerical illustrations for the case of sulphur emissions in Europe.

<sup>12</sup> For a more detailed discussion of the incentive structures for global public goods provision, see Barrett (2001, 2003).

An obvious asymmetry between the provision of public goods to a group of individual consumers and to a group of countries is that countries are of different sizes in terms of population. Going back to the central optimality condition (7), one sees immediately that although all national benefit-cost ratios should, at the optimum, be less than one, they would tend to be higher for large than for small countries, simply because the sum of domestic benefits would be larger. The larger countries would accordingly have a stronger incentive, relatively speaking, to contribute to the public good - assuming that there is no systematic tendency for individual preferences for the public good to be lower in the large countries. In his pioneering analysis of incentives for public goods provision, Olson (1971) drew the conclusion that in public goods negotiations between “large” and “small” members of a community, the large would tend to bear a disproportionate burden of the cost, implying that there would be “exploitation” of the large by the small. But this is a result in positive economics or political economy. Needless to say, in the welfare theoretic framework there can be no such bias; by definition, the cost shares have been optimally allocated between nations, taking due account both of efficiency and equity considerations.

## **8. Concluding remarks.**

The main focus of the present paper has been on the welfare economics of the supply of global public goods. Some people might say that this approach carries utopian thinking in economics to its limits - if not beyond. Since the welfare economics approach to economic policy is frequently criticized for taking a naive view of the political process, this must be even more true for applications to the world as a whole, for which no governmental authority exists. There can be no point in deriving policy rules for a non-existing government.

For my own part, I do not agree with this criticism. On the contrary, I believe that welfare economics is important for policy analysis even in this case. In my opinion, the discussion in Section 7 above of the problems of incentives and implementation demonstrates this clearly. It is common to argue that in the international bargaining about climate treaties or the preservation of world heritage sites, incentives may be biased to favour national rather than global interests. But if we claim that incentives are distorted relative to the achievement of some common good for the world as a whole, we need to have a reasonable idea of what this common good might be, otherwise it is impossible for us to come up with ideas of how incentives could be changed for the common good. In this we as economists can perform a

useful function even though we are not able to define the common good - Adam Smith's "public interest" - with a high degree of precision. What we can do is to explore the consequences of a particular measure of the common good and see where it leads us. In the present discussion the adoption of the Bergson-Samuelson individualistic welfare function has led us to the realization that a policy that achieves global production efficiency - a policy strongly recommended by many economists - is not a necessary outcome of welfare maximization. Whether it is, depends crucially on the existence of systems for the international redistribution of income<sup>13</sup>. Other conceptions of the common good might conceivably lead to other conclusions regarding this problem, and these alternative approaches need to be explored.

These arguments must not be taken to imply that the positive economics of global public goods is of less or even of no interest. This is definitely not true; in fact I believe that the two approaches are strongly complementary<sup>14</sup>. Welfare economics as applied to private production and exchange derives much of its interest from being confronted with the positive theories of private incentives and market equilibrium. It is from this confrontation that we have derived our insights in the conditions for efficiency of market equilibrium and in the trade-off between efficiency and equity. In the same way, positive analyses of international provision of global public goods need to relate to standards of efficiency and justice in the allocation of resources.

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<sup>13</sup> A major limitation of the present discussion is that both national and international redistribution are assumed to take the form of lump sum transfers. A more general treatment would take into account the marginal cost of public funds that arises in domestic economies from the presence of distortionary taxation, as well as the possibly distortive effects of transfers on recipient countries.

<sup>14</sup> This is also the view expressed by Atkinson (2001) in his perceptive discussion of welfare economics in relation to policy discussions in macroeconomics.

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## Appendix A. Global public consumption goods.

The purpose of the Appendix is to present the derivation of the optimality conditions of the main text. In the case of global public consumption goods the problem is to maximize the social welfare function (1), given the utility functions (2) and subject to the constraints (3), (4) and either of the production-consumption equations (5) or (9). We begin with alternative (9), since, once the optimum for this case has been established, the optimum for the case (5) follows directly as a special case.

The Lagrangian can be written as

$$(A1) \quad \Lambda = W(u^{iR}, \dots, u^{nR}; u^{iP}, \dots, u^{mP}) + \lambda(g^R + g^P - G) - \mu^R F^R(x^R, g^R) - \mu^P F^P(x^P, g^P) \\ - \gamma^R (\sum_i x^{iR} - x^R) - \gamma^P (\sum_j x^{jP} - x^P).$$

Letting subscripts denote partial derivatives<sup>15</sup>, the first order conditions for a maximum can be written as

$$(A2) \quad \partial \Lambda / \partial x^{iR} = W_i u_x^{iR} - \gamma^R = 0. \quad (i = 1, \dots, n)$$

$$(A3) \quad \partial \Lambda / \partial x^{jP} = W_j u_x^{jP} - \gamma^P = 0. \quad (j = 1, \dots, m)$$

$$(A4) \quad \partial \Lambda / \partial G = \sum_i W_i u_G^{iR} + \sum_j W_j u_G^{jP} - \lambda = 0.$$

$$(A5) \quad \partial \Lambda / \partial g^R = \lambda - \mu^R F_g^R = 0.$$

$$(A6) \quad \partial \Lambda / \partial g^P = \lambda - \mu^P F_g^P = 0.$$

$$(A7) \quad \partial \Lambda / \partial x^R = -\mu^R F_x^R + \gamma^R = 0.$$

$$(A8) \quad \partial \Lambda / \partial x^P = -\mu^P F_x^P + \gamma^P = 0.$$

The marginal rates of substitution are defined as  $MRS^{iR} = u_G^{iR} / u_x^{iR}$  and  $MRS^{jP} = u_G^{jP} / u_x^{jP}$ . Substituting these expressions into (A4), this equation can be rewritten as

$$\sum_i W_i u_x^{iR} MRS^{iR} + \sum_j W_j u_x^{jP} MRS^{jP} = \lambda,$$

or, using equations (A2) and (A3),

$$(A9) \quad \gamma^R \sum_i MRS^{iR} + \gamma^P \sum_j MRS^{jP} = \lambda.$$

Combining (A5) and (A7) as well as (A6) and (A8), we can derive the expressions for the marginal rates of transformation or the marginal costs of producing the public good:

$$(A10) \quad \lambda / \gamma^R = F_g^R / F_x^R = MC^R.$$

$$(A11) \quad \lambda / \gamma^P = F_g^P / F_x^P = MC^P.$$

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<sup>15</sup> Note the distinction between lower-case  $g$ , which refers to domestic production of the global public good and upper-case  $G$ , which represents the global provision of the good.



Dividing (A9) by  $\lambda$  and substituting from (A10) and (A11), we obtain

$$(A12) \quad \sum_i MRS^{iR}/MC^R + \sum_j MRS^{jP}/MC^P = 1,$$

which is equation (11) of the main text.

Inequality aversion means that the social marginal utility of consumption in the rich country is lower than in the poor country. From (A2) and (A3) this implies that  $\gamma^R < \gamma^P$ . From (A10) and (A11) one then sees that  $MC^R > MC^P$ . This implies that the marginal willingness to pay receives a lower weight in the rich country than in the poor country.

Now assume that there are perfect lump sum transfers both within and between nations. Social marginal utilities will then be equalized between countries, implying from (A2) and (A3) that  $\gamma^R = \gamma^P$  and consequently that  $MC^R = MC^P$ . Denoting by  $MC$  the common value of the marginal cost, equation (7) follows immediately.

## Appendix B. Global public goods as factor of production.

As in Appendix A we begin with the case with no international transfers, so that domestic consumption of the private good is constrained by equations (9). With global public goods as factors of production the public good no longer enters into the consumers' utility functions, so that these become simply  $u^{iR} = u^{iR}(x^{iR})$  and  $u^{jP} = u^{jP}(x^{jP})$ . The production constraints are represented by equations (12), so that the Lagrangian becomes

$$(B1) \quad \Lambda = W(u^{1R}, \dots, u^{nR}; u^{1P}, \dots, u^{mP}) + \lambda(g^R + g^P - G) - \mu^R F^R(x^R, g^R, G) - \mu^P F^P(x^P, g^P, G) \\ - \gamma^R (\sum_i x^{iR} - x^R) - \gamma^P (\sum_j x^{jP} - x^P).$$

The first order conditions for a maximum are

$$(B2) \quad \partial \Lambda / \partial x^{iR} = W_i u^{iR} - \gamma^R = 0. \quad (i = 1, \dots, n)$$

$$(B3) \quad \partial \Lambda / \partial x^{jP} = W_j u^{jP} - \gamma^P = 0. \quad (j = 1, \dots, m)$$

$$(B4) \quad \partial \Lambda / \partial G = -\lambda - \mu^R F^R_G - \mu^P F^P_G = 0.$$

$$(B5) \quad \partial \Lambda / \partial g^R = \lambda - \mu^R F^R_g = 0.$$

$$(B6) \quad \partial \Lambda / \partial g^P = \lambda - \mu^P F^P_g = 0.$$

$$(B7) \quad \partial \Lambda / \partial x^R = -\mu^R F^R_x + \gamma^R = 0.$$

$$(B8) \quad \partial \Lambda / \partial x^P = -\mu^P F^P_x + \gamma^P = 0.$$

Rearranging (B4), we can rewrite this equation as

$$(B9) \quad \mu^R F^R_x (-F^R_G / F^R_x) + \mu^P F^P_x (-F^P_G / F^P_x) = \lambda.$$

The terms in parentheses on the left-hand side are the marginal rates of transformation between the global public good and the private good in the two countries, or the marginal output effects (*MOE*). Dividing by  $\lambda$ , (B9) can be rewritten as

$$(B10) \quad (\mu^R F_x^R / \lambda)(MOE^R) + (\mu^P F_x^P / \lambda)(MOE^P) = 1.$$

Combining (B5) with (B7) and (B6) with (B8), we obtain

$$(B11) \quad (\mu^R F_x^R / \lambda) = (F_g^R / F_x^R)^{-1}, \quad (\mu^P F_x^P / \lambda) = (F_g^P / F_x^P)^{-1}.$$

These expressions are the inverses of the domestic marginal rates of transformation between public and private good production, or the marginal costs of producing the public good.

Inserting (B11) into (B10), we can therefore write

$$(B12) \quad (MOE^R) / MC^R + (MOE^P) / MC^P = 1.$$

This corresponds to the optimality condition (11) for the case of global public consumption goods. In the case of inequality aversion in the social welfare function, one sees from (B2) and (B3) that  $\gamma^R < \gamma^P$ . Therefore, from (B7), (B8) and the definitions in (B11) it follows that  $MC^R > MC^P$ . In deriving the global optimality condition, the marginal output effect in the rich country receives a lower weight than that in the poor country.

If, on the other hand, there are perfect lump sum transfers between the countries, it follows that  $\gamma^R = \gamma^P$  and therefore that  $MC^R = MC^P$ . Letting  $MC$  be the common value of the marginal cost, condition (14) in the main text follows directly from (B12).



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