Foreign Aid and Global Public Goods

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Abstract

After the September 11 disaster the U.S. rediscovered an old international policy to raise the provision of an international public good: foreign aid as a means to raise global security. However, foreign aid may also help to overcome other international problems.

In this paper, we analyze the effect foreign aid on international climate policy. We take account of cost differentials among countries in producing the public good, ancillary benefits of climate policy and alternative technologies independently generating ancillary benefits. We elaborate incentives to provide foreign aid and highlight a new aspect influencing the effects of foreign aid on global public good provision: cost differentials among countries in independently generating ancillary effects of global public goods.

Keywords: Ancillary Benefits, Foreign Aid, Impure Public Goods

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1 Introduction

Global public bads like climate change, the Severe Acute Respiratory Syndrome (SARS) and terrorism were in the public glaze during recent years. Meanwhile, politicians seem to have found a new cure combating such global threats: foreign aid.

In March 2002, the U.S. President George W. Bush proposed the first significant raise in U.S. development assistance in a decade. This represents a 50 percent increase over current development assistance (Diamond 2002: 2). Before, the U.S. aid budget has fallen from 0.24 percent of GDP in the mid-1980s to 0.1 percent in 2002, 'making the United States the least generous of the 22 advanced economies' (Washington Post: 2002). The additional aid funds flow to a selected group of countries, which are committed to political and economic standards of good governance. The aim is to reduce poverty and as President Bush pointed out in his speech at the United Nations Financing for Development Conference in Monterrey, Mexico: *"We fight against poverty because hope is an answer to terror."*

What is suggested by the Bush administration as a means against terrorism, may also help to mitigate other global problems.[1] This general idea has been stressed by José María Aznar, President of Spain, who spoke on behalf of the European Union (EU) at the Monterrey Conference. He pointed out with respect to the EU's development assistance that *"[s]ufficient financial resources must be dedicated to global public goods."* Furthermore, Romano Prodi, President of the European Commission declared at the same conference that *"the EU Member States have collectively set the interim target of 0.39%"* of GNP to be devoted to development aid by 2006.

Reduced poverty may increase the demand for hygienical standards which lower the likelihood of the occurrence and pandemic of new illnesses like SARS. And reduced poverty may also raise the demand for environmental protection, e.g., in the shape of climate change mitigation.

In this paper, we have a closer look on the global public good "greenhouse gas (GHG) abatement policy" and we investigate the impact of foreign aid on the provision levels of such a policy. In our analysis, we take account of cost differentials among countries in the provision of the public good. We also consider joint production properties of climate policy as well as alternative technologies producing ancillary effects of this policy. This highlighting of joint production properties and alternative technologies allows us to elaborate a new aspect of international climate policy: Alternative technologies independently generating side-effects of climate policy may exhibit cost differentials among countries which influence the impact of foreign aid on the global provision of the public good.

Finally, we evaluate the attractiveness of unconditional transfers – from the industrialized world's point of view – as a means to raise the provision of global public goods while taking into account all influences elaborated in our analysis.

[1] On the issue of international public goods providing a rationale for foreign aid when efficiencies in the production of these goods differ among countries, see Jayaraman and Kanbur (1999).

2 Foreign Aid in the Shape of Unconditional Income Transfers

We analyse foreign aid in the shape of unconditional income transfers, i.e., transfers which are not conditional on the transfer receptor's behavior.[2] Income transfers as a means of raising the voluntary provision of public goods are an issue vividly discussed in the scientific literature. An important result is (re)discovered by Warr (1982, 1983), who states that, in an interior Nash equilibrium, redistribution of income among agents is *neutral*. Income transfers are called neutral if they do not affect the total public good provision and the individual agents' consumption of private goods. Prior to this, the neutrality result had already been noticed by Becker (1974), while Barro (1974) had formally demonstrated that neutrality may even hold for intergenerational transfers.

Kemp (1984) extends Warr's 'neutrality theorem' to the case of more than one public good. Boadway, Pestieau and Wildasin (1989) point out that transfers may be neutral even when there are distortions in the shape of taxes and subsidies on private goods or factors, strictly local public goods, or on goods that are public to all. Varian (1994) finds that neutrality may also occur for Stackelberg equilibria. These results suggest that unconditional income transfers would only cause a redistribution of GHG abatement activities among countries while leaving the global abatement level, as well as the individual countries' welfare, unchanged. Therefore, incentives for foreign aid in the shape of unconditional transfers would not exist.

2.1 Impacts of Foreign Aid on the Public Good Provision Level

The impacts of unconditional transfers on the global GHG abatement level can be comfortably analysed in the framework of a two-stage game. Throughout the analysis, countries' preferences are presented in characteristic rather than in commodity space.[3]

After an illustration of the neutrality result, we investigate in which circumstances the neutrality of unconditional income transfers may not hold, and also examine whether these circumstances might raise the attractiveness of transfers from a transfer-paying country's point of view. Since countries cannot be forced to pay transfers, such an increase in attractiveness would be a prerequisite for the (voluntary) provision of transfers.

More precisely, in order to analyse the causes of the non-neutrality of foreign aid as well as their influences on the attractiveness of transfer payments, we proceed as follows: in a first step, the impact of marginal cost differentials of abating GHGs on the effects of transfers is investigated. Then, in a second step, the influence of differing abatement motives is described. In a last step, we allow for the implementation of technologies generating the ancillary effects of GHG abatement activities independently and analyse how their application affects the impacts of unconditional income transfers. The general setting we employ widely follows an approach suggested by Andreoni (1986, 1989, 1990).

[2] The issue of conditional transfers as a means to raise the global climate protection level is discussed by Rübbelke (2002).

[3] For a similar approach which also considers three commodities, see Rübbelke (2003), who analyses differing abatement incentives in a comparative statics model.

2.1.1 The Model

Within a world of n countries, each country is assumed to consume three different commodities. The first commodity represents a bundle of private goods. Its unit price is normalized to unity. While the considered country consumes y_1 units of the first commodity, each unit of the commodity is assumed to generate exactly one unit of a private characteristic. Hence, country i's consumption of this private good as well of the associated provision of the private characteristic can be equally denoted y_{1i}.

The second commodity is also a private goods bundle. This commodity is neglected in the first part of our analysis, i.e., temporarily, we set its consumption level equal to zero.

The third commodity represents the impure public good 'GHG abatement measures'. Both a pure public and a private characteristic are generated by GHG abatement measures. The *pure public characteristic* subsumes all effects generated by GHG abatement measures that can be enjoyed globally, irrespective of which country abates. The pure public characteristic provided by GHG abatement measures is climate stabilization. No country can be excluded from its consumption and it exhibits non-rivalry. Benefits induced by climate stabilization are the primary benefits of GHG control. GHG abatement measures also provide a *private characteristic* with a pure regional influence that can be exclusively enjoyed by countries providing the climate protection.[4] Such a beneficial characteristic is, e.g., an improved air quality caused by the mitigation of the emissions of pollutants which are associated with the emission of CO_2. Consider, when CO_2 emissions are reduced, emissions of many other regional pollutants like SO_2 and NO_X are also abated. Benefits countries enjoy through the consumption of the private characteristic are so-called ancillary or secondary benefits of climate policy.

In our model it is assumed that one unit of one country i's impure public good production generates one unit of a pure public characteristic, and additionally produces one unit of the second private characteristic, which could also generated by the second commodity. Hence, the total amount of the second private characteristic y_{2i} enjoyed by country i is equal to the amount of the public good x_i produced by country i as long as we set the amount of the second commodity equal to zero. The total consumption X of the pure public characteristic by the considered country is the sum of its own contribution x_i and the other $(n-1)$ countries' contributions $\tilde{X}_i$:

$$X = x_i + \tilde{X}_i. \tag{1}$$

In *stage 1* of the game, countries can voluntarily transfer income and in *stage 2*, each country determines its contribution to the public good. It is assumed that, before the game is played, every country i $(i = 1, .., n)$ already provides GHG control, but the abatement levels may vary among countries. Furthermore, while income is redistributed among countries by unconditional transfers, no country loses more of its private (monetary) income I_i than it originally contributed to the protection of the world's climate. Consider

[4] Because the climate protecting country can enjoy this characteristic exclusively, this characteristic has a private good property from this country's point of view.

the utility maximization problem of country i, where prices of the commodities are put equal to unity:

$$\max_{y_{1i}, y_{2i}, X} U_i(y_{1i}, y_{2i}, X)$$

$$\text{s.t.} \qquad (2)$$

$$\begin{aligned} I_i &= y_{1i} + y_{2i}, \\ y_{2i} &= X - \tilde{X}_i. \end{aligned}$$

The maximization problem (2) implicitly contains two polar cases:

- *Pure Public Good Case:* Country i considers 'GHG abatement activity' as a pure public good and the utility function can be expressed as $U_i = U_i(y_{1i}, X)$.
- *Private Good Case:* Country i neglects public benefits of GHG control. Because it only regards the private ancillary benefits of GHG abatement measures, the utility function is represented by $U_i = U_i(y_{1i}, y_{2i})$.

In a more compact way, the utility maximization problem can be written as

$$\max_X U_i(I_i + \tilde{X}_i - X, X - \tilde{X}_i, X). \qquad (3)$$

By the usual first-order condition, i.e., differentiating (3) with respect to X and equating to zero, we can solve for country i's optimal consumption level of the public characteristic. The solution is a function of the exogenous components I_i and $\tilde{X}_i$ of the optimization problem (3):

$$X = f_i(I_i + \tilde{X}_i, \tilde{X}_i). \qquad (4)$$

Therefore, country i's optimal own contribution to GHG abatement is

$$x_i = X - \tilde{X}_i = f_i(I_i + \tilde{X}_i, \tilde{X}_i) - \tilde{X}_i. \qquad (5)$$

The first argument in f_i comes from the pure public good dimension of the utility function in (3). The derivative of f_i with respect to the first argument, f_{i1}, represents country i's marginal propensity to provide GHG control activities for climate protection reasons. This marginal propensity tends to be larger, the higher the marginal primary benefits enjoyed by country i. The private characteristic y_1 and the pure public characteristic X are assumed to behave like normal goods (considering full or virtual income),[5] and hence $0 < f_{i1} < 1$ holds.

[5] The full or virtual income may also be denoted 'hypothetical income' or 'social income'. Becker (1974: 1063) defines 'social income' as *"the sum of person's own income (his earnings, etc.) and the monetary value to him of the relevant characteristics of others"*. In contrast, private income is simply the monetary income of a person.

2.1.2 The Neutrality Result

In order to illustrate that the first argument in f_i stems from the pure public good dimension and to show how transfers would affect the provision of the public good if only this argument were regarded, we consider the pure public good case in a two-country world. Countries a and b consume the private characteristic y_1 as well as the pure public characteristic while it is assumed that no secondary characteristics are generated by GHG control measures. Then, the utility function becomes $U_i = U_i(y_{1i}, X) = U_i(I_i + \tilde{X}_i - X, X)$ and f_i reduces to $f_i = f_i(I_i + \tilde{X}_i)$, i.e., only the first argument of f_i in (4) plays a role. Consequently, the optimal consumption level X only depends on the full income $I_i + \tilde{X}_i$ and each country treats the other country's provision of climate protection $\tilde{X}_i$ as a perfect substitute for own private income I_i. If one country decreases its contribution to the public characteristic X slightly, while simultaneously paying the saved expenses in transfers to the other country, these transfers fully compensate the other country for the reduction in the provision of the public characteristic, i.e., the other country's full income $I_i + \tilde{X}_i$ remains constant. Since only the full income matters to the countries, no change in the individual countries' consumption patterns arises, although their contribution to the public good changes with income redistribution. The receptor of the transfers utilizes the received transfers in order to buy more of the public good itself. Thus, the individual countries' consumption of the private good and the total amount of GHG control remain unchanged. Since each country is indifferent to which country contributes to climate protection, any constellation of transfers and contributions that leaves (y_{1i}, X) unchanged for both countries can be supported as an equilibrium. Because redistribution of income is neutral, countries have no incentives to provide foreign aid. The neutrality 'holds regardless of differences in individual preferences and despite differences in marginal propensities to contribute to the public good' (Warr 1983: 207).

The neutrality result and the missing incentives to provide foreign aid can be illustrated by employing a graphical method developed by Buchholz (1990). In Figure 1, both countries' income expansion paths $y_{1a} = e_a(X)$ and $y_{1b} = e_b(X)$ are depicted.[6] An income expansion path represents the locus of all combinations of consumption of y_{1i} and X in the y_{1i}–X plane along which the marginal rate of substitution (MRS_i) of country i between its consumption of X and of y_{1i} equals its marginal rate of transformation (p_i) between its consumption of X and of y_{1i}. An own-welfare maximising country i chooses an aggregate amount of X that equates its MRS_i to p_i and, therefore, it will choose a position located on its income expansion path. Due to the "normal goods" assumption, the income expansion paths are strictly monotonic increasing. By taking account of $p_a = p_b = 1$, we obtain the following feasibility constraint (the asterisks indicate values associated with the Nash equilibrium):

$$I = I_a + I_b = e_a(X^*) + e_b(X^*) + X^*. \tag{6}$$

In Figure 1, the sum of both countries' private incomes equals half the length of the

[6] Consider that the transformation functions of both countries have the same slopes in the direction of the ordinate. The income expansion path is constituted by the tangential points between the indifference and transformation curves. On income expansion paths see standard textbooks like Hirshleifer and Glazer (1992: 94–97).

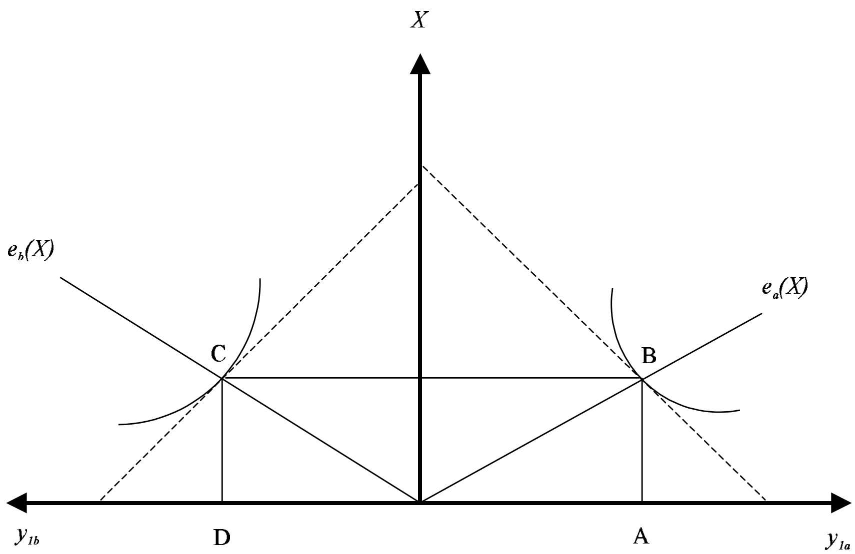

Figure 1: Nash Equilibrium for Agents with Identical p_i

perimeter of the rectangle ABCD. Because e_a and e_b are continuous and strictly increasing in X^*, there exists exactly one public good level for which (6) holds. Consequently, equation (6) implicitly determines the countries' consumption levels of private and public goods in the Nash equilibrium as a function of the sum of both countries' incomes. Since income redistribution among both countries would not change the sum of their incomes, such a redistribution is neutral with respect to the countries' consumption levels of private and public goods.

2.1.3 Cost Differentials Among Countries in Producing the Public Good

However, the neutrality result is invalid if marginal costs of providing a public good differ among agents (see Buchholz and Konrad 1995; Konrad and Lommerud 1995; Ihori 1996). In such cases, which are much more likely, foreign aid provision may have an impact on the level of global climate protection. This is illustrated next for our two-country world. By closely following the instructive reasoning of Buchholz and Konrad (1995) as well as Althammer (1998), we explain why countries may have incentives to provide unconditional transfers.

Let us still assume that the marginal climate protection costs and, hence, the prices p_i of the pure public characteristic are constant, but suppose that they differ between countries a and b, so that $p_a > p_b$. As prices differ, a general normalization of prices to unity is no longer possible. Instead, the Nash supply functions explicitly contain prices: $x_i = f_i(I_i + p_i\tilde{X}_i, p_i) - \tilde{X}_i$.

In a first step, it is assumed that country a is endowed with the whole private income, that is, $I_a = I$. Without the provision of foreign aid, country a chooses an allocation

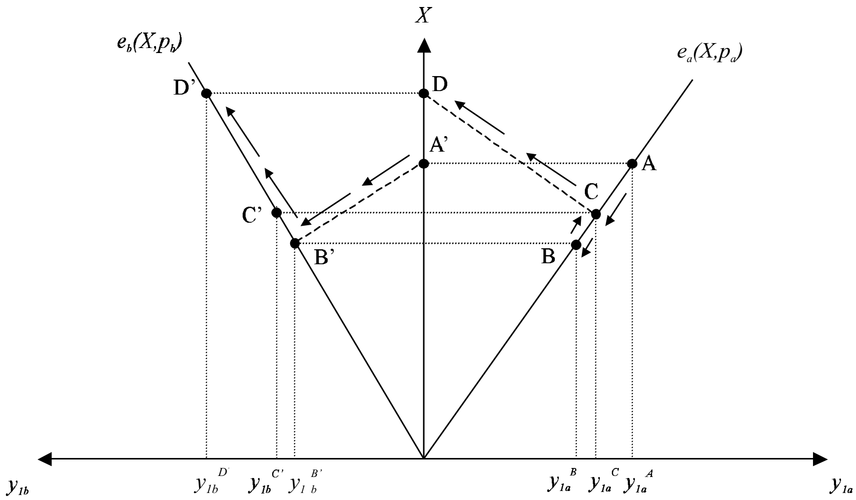

Figure 2: Foreign Aid Provided by Country a to b

(y_{1a}^A, X^A), which is depicted by point A in Figure 2.[7] Because country b has no income, it does not contribute to the public good and $y_{1b} = 0$. Its position A' is not located on its income expansion path e_b. Now, let country a start to transfer income to country b. As long as country b's income remains low, it still does not contribute to the public good and transfer payments from a are completely spent on b's consumption of the private good. Hence, country a's consumption level of the private and public goods decreases and it moves along its income expansion path downwards, while its utility level declines.

As point B is the lowest location on country a's income expansion path where country b remains a non-contributor: it holds that $x_b = 0$ and $y_{1b} = I_b$. When the transfer becomes so large that threshold B on country a's income expansion path is reached, country b starts to contribute to climate protection.

By summing up the transformed budget constraints $x_a = \frac{1}{p_a}(I_a - y_{1a})$ and $x_b = \frac{1}{p_b}(I_b - y_{1b})$ of countries a and b, respectively, we obtain the feasibility constraint $X^* = \frac{1}{p_a}(I_a - y_{1a}^*) + \frac{1}{p_b}(I_b - y_{1b}^*)$, which can also be expressed as

$$\frac{I_a}{p_a} + \frac{I_b}{p_b} = \frac{1}{p_a} e_a(X^*, p_a) + \frac{1}{p_b} e_b(X^*, p_b) + X^*. \tag{7}$$

We use this constraint in order to compare the public good provision levels in AA' and BB': Because country b does not have any private income in AA', (7) becomes

$$X^A + \frac{e_a(X^A, p_a)}{p_a} = \frac{I}{p_a}. \tag{8}$$

With respect to BB' we have to consider that $I_a = I - I_b$, $I_b = e_b$ and that the total

[7] This depiction closely follows the figures in Buchholz and Konrad (1995: 496).

public good provision level X^B prevails. Hence, we obtain

$$\begin{aligned} X^B &+ \frac{e_a(X^B, p_a)}{p_a} + \frac{e_b(X^B, p_b)}{p_b} = \frac{I_a}{p_a} + \frac{I_b}{p_b} \\ = &\quad \frac{I - e_b(X^B, p_b)}{p_a} + \frac{e_b(X^B, p_b)}{p_b} \end{aligned} \tag{9}$$

or

$$X^B + \frac{1}{p_a}[e_a(X^B, p_a) + e_b(X^B, p_b)] = \frac{I}{p_a}. \tag{10}$$

By equating (10) to (8), we get

$$X^B + \frac{1}{p_a}[e_a(X^B, p_a) + e_b(X^B, p_b)] = X^A + \frac{e_a(X^A, p_a)}{p_a}. \tag{11}$$

Proposition: Because $e_b(x^B, p_b)$ is positive and e_a is increasing in X,

$$X^B < X^A. \tag{12}$$

Proof: From (11) we obtain

$$p_a(X^A - X^B) = e_a(X^B, p_a) + e_b(X^B, p_b) - e_a(X^A, p_a). \tag{13}$$

Assume that $X^B \geq X^A$. Then, the left-hand side of (13) is non-positive, while the right-hand side is positive, since $e_b(X^B, p_b)$ is positive and e_a is increasing in X. Consequently, for $X^B \geq X^A$ equation (13) cannot hold, and hence $X^B < X^A$.

A further income transfer from country a to country b induces both countries to move outwards along their income expansion paths while they both contribute to the public good. Both countries' welfare increases relative to the allocation $(y^B_{1a}, y^{B'}_{1b}, X^B)$. This result which Ihori (1996: 148) calls *weak paradoxical* can be observed from the feasibility constraint (7): An income transfer $\Delta I > 0$ from the less productive country a to country b increases the left-hand side of (7) by $[(1/p_b) - (1/p_a)](\Delta I)$, since $p_a > p_b$. Hence, the right-hand side of (7) also has to rise. Therefore, country a displays – as Althammer (1998) calls it – a less-is-more effect: The welfare of the transfer-providing country grows, since the more productive country's contribution to the public good becomes positive and outweighs the utility loss caused by the reduction in the private income of the less productive country a.

However, a further decrease in its private income will lead country a to a point C, where it stops contributing to the public good. Therefore, it is $I_a = e_a(X^C, p_a)$ at point C. By considering that the total public good provision is X^C and $I_b = I - I_a$ and substituting $I_a = e_a(X^C, p_a)$, we obtain the following feasibility constraint

$$\begin{aligned} X^C &+ \frac{e_a(X^C, p_a)}{p_a} + \frac{e_b(X^C, p_b)}{p_b} = \frac{I_a}{p_a} + \frac{I_b}{p_b} \\ = &\quad \frac{e_a(X^C, p_a)}{p_a} + \frac{I - e_a(X^C, p_a)}{p_b} \end{aligned} \tag{14}$$

or, equivalently,

$$X^C + \frac{1}{p_b}[e_a(X^C, p_a) + e_b(X^C, p_b)] = \frac{I}{p_b}. \tag{15}$$

Combining (10) and (15) yields

$$\begin{aligned} &p_b X^C + e_a(X^C, p_a) + e_b(X^C, p_b) \\ &= p_a X^B + e_a(X^B, p_a) + e_b(X^B, p_b). \end{aligned} \tag{16}$$

Proposition: Since e_a and e_b are increasing in X and $p_a > p_b$, it follows that

$$X^C > X^B. \tag{17}$$

Proof: From (16) we obtain:

$$\begin{aligned} p_a X^B - p_b X^C = \quad & e_a(X^C, p_a) + e_b(X^C, p_b) \\ & - e_a(X^B, p_a) - e_b(X^B, p_b). \end{aligned} \tag{18}$$

Assume that $X^C < X^B$. Then, the left-hand side of (18) is positive, while the right-hand side is negative, since e_a and e_b are increasing in X. Consequently, for $X^C < X^B$, equation (18) cannot hold. Next, assume that $X^C = X^B$. Then, because $p_a > p_b$, the left-hand side of (18) is positive, while the right-hand side is equal to zero. Thus, for $X^C = X^B$, equation (18) cannot hold either. We can conclude that (18) might only hold for $X^C > X^B$.

With further rising transfers from country a to country b, country b moves along $e_b(X, p_b)$ until D' is reached, where $I = I_b$. Country a moves upwards along CD until it finally reaches D, where its entire private income has been transferred to country b.

Now, let us analyse under which conditions countries may have incentives to provide foreign aid in the shape of unconditional transfers. Buchholz and Konrad (1995: 498) prove that the more productive country never has an incentive to transfer income to the less productive country. In contrast, the less productive country a may well have incentives to provide transfers to the highly productive country b. Whether this is the case crucially depends on the position of the less productive country before the game starts. Possible positions are located along ABCD.

In the range where both countries provide positive amounts of the public good, which is the *interval BC*, country a can definitely improve its welfare by providing income transfers to country b until C is reached. Country a may also increase its welfare by paying transfers to country b if it is located in the *interval CB*, where country a is the only provider of the public good. But then, the transfers have to move the transfer-paying country to a position which is located further outwards on its income expansion path. A move to the inside induced by transfers would reduce the transfer-paying country's welfare. A sufficient condition for country a to strive even for a location on the curve CD is that the indifference curve at C is flatter than the curve CD at C, which is true if $p_a > p_b + \frac{d}{dX}e_b(X^C, p_b)$.[8]

[8] The indifference curve at C is more flat than the curve CD at C, when the value of the slope of the indifference curve at C, which equals the slope of the transformation curve, $-(1/p_a)$, exceeds the value of the slope of the curve CD at C which is equal to $\frac{-1}{p_b + (de_b(X^C, p_b)/dX)}$. By some straightforward manipulations we obtain: $p_a > p_b + \frac{d}{dX}e_b(X^C, p_b)$.

Similarly, for a position within the *interval CD* it is a sufficient condition for a country to provide transfers that the slope of the indifference curve passing through this position is flatter than the slope of curve CD at this position.[9] If country a is in a position located in the *interval AC*, it may be advantageous for it not to pay transfers to country b. In order to exclude such an inefficient specialization, we may assume that C on $e_a(X, p_a)$ lies above A. Then, interior equilibria would exist which yield more climate protection and higher welfare for country a than the best possible stand-alone position where country a gets the whole private income: Starting from position A, where country a gets the whole private income, a redistribution of income which leads – over B – to the segment AC, will raise the equilibrium climate protection level and both countries' welfare.

Let us derive the conditions which have to hold in order to get this constellation. From (15) we get for the feasibility constraint in C:

$$I = p_b X^C + e_a(X^C, p_a) + e_b(X^C, p_b). \tag{19}$$

If $X^C > X^A$, then

$$I > p_b X^A + e_a(X^A, p_a) + e_b(X^A, p_b), \tag{20}$$

because of the monotony of $e_i(X, p_i)$. From (8) it follows that $I - e_a(X^A, p_a) = p_a X^A$, which can be substituted into (20) and yields after some modifications

$$(p_a - p_b)X^A > e_b(X^A, p_b). \tag{21}$$

Provided that (21) holds, the more productive country specializes in the abatement of GHGs regardless of the distribution of income I before the game starts. The left-hand side of (21) stands for the financial resources that can be saved when the more productive country b provides X^A. The right-hand side stands for the private good consumption level country b would require in order to reach its income expansion path given the public good level X^A. Hence, the higher the cost differential $(p_a - p_b)$ and the smaller $e_b(X^A, p_b)$, the more likely it is that (21) will hold. $e_b(X^A, p_b)$ tends to be smaller, the *weaker the transfer-receiving country's preferences are for the consumption of the private good* and/or *the weaker the transfer-providing country's preferences are for climate protection* in AA':

- *Weak preferences for the consumption of the private good* imply an income expansion path which is located above the paths found in cases where preferences for the consumption of the private good are stronger, ceteris paribus. Hence, less of the private good is required by country b in order to reach the location where it starts to contribute to the public good.
- *Weak preferences for climate protection* are represented by an income expansion path which is located below the paths found in cases of stronger preferences for climate protection, ceteris paribus. Thus, given the income level I_a, the foreign-aid providing country a's starting position is associated with a lower public good provision X^A. Since $e_b(X, p_b)$ is strictly increasing in X, a lower X^A implies a lower $e_b(X^A, p_b)$, too.

[9] For an extensive discussion of transfers of a country located in or moving to the interval CD, see Buchholz and Konrad (1995).

We can conclude from our analysis that it might be advantageous for countries to provide foreign aid when the more productive countries take the role of transfer receptors. Such welfare-enhancing transfers are associated with a rise in global GHG abatement.

2.1.4 Joint Production Properties of Climate Policies

Let us next turn to the second argument in f_i in order to look at the impact of the impure publicness of GHG control measures on the effects of unconditional transfers. The second argument in f_i stems from the second argument of the utility function in (3), which represents the jointly generated private characteristic dimension of the utility function. Considering its joint production property, other countries' provision of GHG control measures is no longer a perfect substitute for country i's private income – not even in the absence of differences in marginal abatement costs among countries. By its own provision of the impure public good 'GHG abatement activity' country i derives benefits from the pure public characteristic as well as the jointly generated private characteristic. From other countries' contributions, country i only derives pure public primary benefits. Thus a country would not be indifferent to the possible constellations that leave (y_{1i}, X) unchanged, but would prefer the constellation that provides it with the most ancillary benefits.

The partial derivative of f_i with respect to the second argument represents the marginal propensity to contribute to world-wide GHG control activities for private secondary reasons and is denoted f_{i2}. The marginal propensity tends to be higher, the higher the marginal ancillary benefits. In order to analyse the range of values of f_{i2}, the subsequent thought experiment is conducted with respect to the impure public good case and its polar cases (pure public and private). Suppose that country i's private income I_i is reduced by one euro and the other countries increase their provision of the impure public good, $\tilde{X}_i$, by one euro simultaneously. Hence, $I_i + \tilde{X}_i$ remains constant.

As mentioned above, in the *pure public good case*, i.e., when there is no jointly generated private characteristic, country i will respond to the fall in its private income and the other countries' rise in their contribution to the public good $\tilde{X}_i$ by the same value, with a decline in its own provision level x_i, which completely offsets the rise in $\tilde{X}_i$. It holds, therefore, that $\partial f_i/\partial I_i = \partial f_i/\partial \tilde{X}_i = f_{i1}$ and $f_{i2} = 0$.

The *impure public good case* is more complex, since both effects, f_{i1} and f_{i2}, have to be taken into account. However, in the considered example the value of the first argument in f_i remains constant because country i's private income decreases by one euro and the other countries' provision $\tilde{X}_i$ rises by one euro. Hence, f_{i2} is isolated. Although $I_i + \tilde{X}_i$ remains constant, the welfare of country i declines since it loses some of the jointly generated private characteristic. If it is assumed that both private characteristics behave like normal goods, the decline in welfare will induce a reduction in the consumption levels of both private characteristics. Since the consumption of y_{1i} becomes lower than in the before-transfer situation, there is a mitigating impact of the jointly generated private characteristic y_{2i} on the income-transferring country's reduction in the provision of the impure public good. The rise in $\tilde{X}_i$ will not be completely offset by country i's decrease in the provision of the impure public good (which is lower than one euro). It holds, therefore, that $\partial f_i/\partial I_i \leq \partial f_i/\partial \tilde{X}_i$, and since $\partial f_i/\partial \tilde{X}_i = f_{i1} + f_{i2}$, this implies that $f_{i2} \geq 0$.

In the *private good case*, i.e., when only private characteristics are considered and the public characteristic is left out of the utility function, country i's contribution is independent of the other countries' contributions: $\partial f_i/\partial \tilde{X}_i = f_{i1} + f_{i2} = 1$.

The separation of the propensities to contribute to world-wide GHG control activities into pure public and jointly generated private components allows for indexing the individual countries according to their marginal propensity to contribute to world-wide GHG control activities for private secondary reasons. To achieve this, simply the following question is analysed: If country i had to give up one euro of income I_i, by how much would other countries' GHG abatement contributions $\tilde{X}_i$ have to rise in order to keep the total GHG abatement level unchanged? From totally differentiating (4) and setting $dX = 0$ we get

$$dX = f_{i1}(dI_i + d\tilde{X}_i) + f_{i2}d\tilde{X}_i = 0. \tag{22}$$

Rearranging and denoting $R_i := -\frac{d\tilde{X}_i}{dI_i}\Big|_{dX=0}$ gives

$$R_i = \frac{f_{1i}}{f_{1i} + f_{2i}} = \frac{1}{1 + (f_{2i}/f_{1i})}. \tag{23}$$

This ratio describes the properties stated above:

- If no joint product, and therefore, no ancillary benefits are generated, then the propensity to contribute to world-wide GHG control activities for private secondary reasons, f_{i2}, is equal to zero and R_i becomes unity.
- If there are only private and no public characteristics enjoyed, then $R_i = f_{i1}$ since $f_{i1} + f_{i2} = 1$.
- In the impure case, R_i is lower, the higher the marginal propensity to contribute for secondary private reasons compared with the marginal propensity to contribute for climate protection reasons; but R_i remains within the range $f_{i1} \leq R_i \leq 1$. If $R_i > R_j$, then country j's propensity to contribute for secondary private reasons relative to the propensity to contribute for climate protection reasons exceeds the corresponding ratio of country i.

The index R_i will be employed in the subsequent analysis of the effect of foreign aid on the impure public good provision. In a first step, we differentiate the Nash supply function (5) for each country i:

$$\begin{aligned} dx_i &= f_{i1}(dI_i + d\tilde{X}_i) + f_{i2}d\tilde{X}_i - d\tilde{X}_i \\ &= (f_{i1} + f_{i2} - 1)d\tilde{X}_i + f_{i1}dI_i. \end{aligned} \tag{24}$$

Substituting $(dX - dx_i)$ for $d\tilde{X}_i$ and rearranging yields

$$\begin{aligned} dx_i &= \frac{f_{i1} + f_{i2} - 1}{f_{i1} + f_{i2}}dX + \frac{f_{i1}}{f_{i1} + f_{i2}}dI_i \\ &= \frac{f_{i1} + f_{i2} - 1}{f_{i1} + f_{i2}}dX + R_i dI_i. \end{aligned} \tag{25}$$

By summing across all n countries and solving for dX we get

$$dX = \varrho \sum_{i=1}^{n} R_i dI_i, \tag{26}$$

where

$$\varrho = \left(1 + \sum_{i=1}^{n} \frac{1 - f_{i1} - f_{i2}}{f_{i1} + f_{i2}}\right)^{-1}.$$

We have shown above that if climate protection is a pure public good, foreign aid provision has no effect on the total provision of the public good. Indeed, if the value of R_i for the pure public good case ($R = 1$) is substituted into equation (26) and it is taken into account that although income transfers cause changes in single countries' private incomes, the sum of all countries' private incomes is not affected, i.e., $\sum_{i=1}^{n} dI_i = 0$, then the change in X becomes zero.

If climate protection is considered to be an impure public good, neutrality does not necessarily hold. This can be most easily illustrated for the case of transfers which only take place between two countries, so that $d\mathbf{I} = (dI_1, dI_2, dI_3, ..., dI_n) = (dI, -dI, 0, ..., 0)$. Consequently, (26) becomes

$$dX = \varrho(R_1 - R_2)dI. \tag{27}$$

Since $0 < \varrho \leq 1$, it holds that $sign(dX) = sign(R_1 - R_2)$. Therefore, transfers will increase the total provision of GHG control, if the sum of the i coefficients R_i weighted by the i income changes exceeds zero (with $i = 1, ..., n$). Hence, foreign aid has a GHG abatement-enhancing impact, if the ratio between the marginal propensity to contribute for secondary private reasons and the marginal propensity to contribute for climate protection reasons in the transfer receptor group is lower than in the group providing the transfer.

2.1.5 Alternative Technologies

What has been omitted so far is the possibility of providing the jointly generated private characteristic by means of technologies which are independent of GHG control. In contrast to CO_2, the emission reduction of several pollutants emitted in association with CO_2 can be realized by means of 'end of pipe' technologies. The emissions of SO_2 can be reduced by flue-gas desulphurization and NO_X as well as CO emissions can be diminished by catalytic converters, for example.

While the impurity of the public good 'GHG abatement activity' has been widely neglected in – at least, theoretical approaches of – the economic climate change literature, this holds even more for alternative technologies producing ancillary effects independently of GHG control and their impacts on the effects of foreign aid. Productivity differentials in the application of an alternative technology prevailing among countries could induce international unconditional transfers to have a positive or a negative impact on the global climate protection level.

Suppose that in a two-country world both countries are equally effective in producing the impure public good and the associated characteristics y_2 and X. However, let us assume that the countries are not equally effective in producing ancillary effects independently of GHG control, i.e., they face different prices of the private characteristic y_2 when it is generated independently of GHG control.[10] Let country 1, which we assume to have some comparative disadvantage in producing secondary effects independently of GHG control, implement the alternative technology in addition to its climate control. Country 2 could also implement such a technology (and may indeed have implemented it already) but at a lower unit cost. Now we suppose that country 2 provides foreign aid to the less productive country 1, which responds with a rise in its provision of GHG control. The transfer-paying country 2 simultaneously reduces its provision of GHG control. Country 1 derives additional ancillary benefits from its increased GHG control efforts. As a result, therefore, it could reduce its costly independent technology application and – if we continue to assume that the single characteristics behave like normal goods – use part of the financial resources released for the additional production of the impure public good. In contrast, country 2's reduction in climate protection efforts is accompanied by a decrease in its consumption of jointly generated secondary effects. It could raise its consumption of these effects again by an increase in its comparatively cheap independent technology application. In order to finance the (additional) implementation, it has to give up part of the consumption of the other goods. Hence, its provision of GHG control decreases further. Although its impure public good provision declines, its consumption of the public characteristic rises because of the other country's enhanced GHG abatement. The rise in public characteristic consumption is accompanied by a growing consumption of both private characteristics.

The production of goods in our two-country world is now organized more efficiently and the 'whole cake' for both countries has increased. Similar to the pure public good case with cost differentials in producing the public good, the consumption level of all (three) characteristics in both countries will be enhanced by the more efficient production scheme. The foreign-aid providing country gains from the higher global provision of the public characteristic which results from the higher provision in the transfer-receiving country. Because the consumption of all characteristics in both countries has increased, each country's welfare as well as global welfare has grown.

2.1.6 Corner Solutions

Another reason why neutrality may not hold is discussed by Bergstrom, Blume and Varian (1986). In their investigation they discover that even in the pure public good case without jointly generated private characteristics and with equal abatement costs among countries, neutrality of income redistribution may not hold. They deviate from the assumptions made here by allowing countries not to contribute to the public good at all and find that transfers from non-contributors to contributors will increase the total provision of the pure public good. But the total contribution might also rise if there are transfers from contributing countries to non-contributing countries, since some of the latter may be induced – by the transfers – to contribute. Even redistribution among contributing

[10] Of course, the unit price of the independent generation of y_2 has to be lower than the unit price of the impure public good, otherwise, y_2 would not be produced independently.

countries may increase total contributions, but this would require the set of contributing countries to decrease.

2.1.7 Non-neutrality of Foreign Aid

While we considered interior solutions, we found three reasons for non-neutrality of foreign aid. These reasons are now briefly reviewed and their welfare implications are highlighted.

1. *Marginal GHG Abatement Cost Differentials:* We illustrated that countries with high marginal GHG abatement costs could have incentives to voluntarily provide foreign aid to countries with low marginal GHG abatement costs. The transfers induce the foreign-aid receptors to raise their provision of GHG control, and because of the cost advantage in the transfer receiving countries' abatement, the global abatement level rises beyond the before-transfer state. In this case an unconditional transfer is welfare-enhancing for the transfer providers as well as for all the other countries.

2. *Differing GHG Abatement Motives:* We further found that foreign aid may also have a positive impact on the global GHG abatement level when the ratio between the marginal propensity to contribute for secondary private reasons and the marginal propensity to contribute for climate protection reasons is lower in the foreign-aid receptor countries than in the group providing the transfers. Although the different motives among countries to produce the public good may cause transfers to induce a rise in the global GHG abatement level, this aspect will not strengthen the transfer payers' incentives to provide transfers, since the rise in the GHG abatement level is at their expense.

3. *Productivity Differentials in the Independent Generation of Secondary Effects:* If we allow for the implementation of technologies which generate the private characteristic of GHG control independently, then the neutrality result may become invalid although no productivity differentials in producing the impure public good prevail. When productivity differentials exist among countries in the independent production of the public good's private characteristic and the more productive countries pay the transfers, foreign aid has a positive impact on the global GHG abatement level because the production of characteristics becomes more efficiently organized. Each country's consumption of the single characteristics increases provided these characteristics behave like normal goods. Hence, a positive effect on all countries' welfare arises.

The latter two reasons are both associated with the impure publicness of GHG abatement activity. If we consider only one ancillary effect, these reasons can be treated as being largely mutually exclusive, i.e., we may either disregard alternative technologies generating this ancillary effect independently or we may allow the implementation of such technologies. With respect to the former possibility, we have to follow the reasoning under item 2. If we allow for independent technologies, item 3 becomes relevant.

3 Incentives to Provide Foreign Aid

As our results suggest, foreign aid from the industrialized to the developing world tends to raise welfare in the industrialized as well as the developing countries, if developing countries have a comparative advantage in providing climate protection. Marginal GHG abatement costs in developing countries are indeed largely assessed to be lower than in industrialized countries (see IPCC 1996: 301–335; Heister 1997: 261; as well as Hackl and Pruckner 2001: 12).[11] Hence, when the aspect of marginal GHG abatement cost differentials is considered, unconditional income transfers could indeed be in both the industrialized and developing countries' interest.

However, the impact of differing GHG abatement motives on the effects of industrialized countries' transfers is ambiguous since it is not obvious at all whether the quotient between the marginal propensity to contribute for secondary private reasons and the marginal propensity to contribute for climate protection reasons in the industrialized world exceeds the one in the developing countries' group. Furthermore, the possibility of generating secondary effects independently of GHG control affects the impact of differing GHG abatement motives. But let us temporarily set aside independent technologies and consider the aspect of differing GHG abatement motives in an isolated way. Afterwards, the impact of independent technologies on the effects of transfers will be integrated into our analysis.

The marginal propensity to contribute for secondary reasons tends to be lower, the lower the marginal ancillary benefits, while the marginal propensity to contribute for climate protection reasons tends to be higher, the higher the marginal primary benefits. Consequently, foreign aid tends to increase the GHG abatement activities if the ratio between marginal secondary benefits and marginal primary benefits of GHG abatement in the transfer receptor group is lower than in the group providing the transfer. Let us have a closer look at the marginal benefits in developing and industrialized countries. Tol (1999) distinguishes nine major world regions.[12] The marginal damage from CO_2, CH_4 and N_2O emissions is found to be greatest in less developed regions such as Africa, Latin America, South and South-East Asia, while the lowest marginal damage is attributed to OECD countries, Central and Eastern Europe and the former Soviet Union (Tol 1999: 79). Therefore, the marginal primary benefits of GHG control in the developing world tend to exceed the ones in the industrialized world. However, it should be stressed that '[a]ssessing greenhouse damage is not possible without accounting, in one way or another, for the huge uncertainty prevailing in the global warming debate' (Fankhauser 1995: 58). This especially holds when benefits have to be estimated for single countries or regions: 'Estimates of the regional climatic impacts of global warming are still inconsistent across different models, and economic studies have made little progress in estimating impacts, particularly in low-income countries' (Nordhaus 1998: 21).

As Rübbelke (2002) elaborates, the estimated proportions between marginal ancillary

[11] Criqui, Mima and Viguier (1999: 589) compare marginal CO_2 abatement costs of different countries and stress that costs of reducing a given quantity of carbon may vary widely even among OECD countries.

[12] OECD-America, OECD-Europe, OECD-Pacific, Central and Eastern Europe and the former Soviet Union, Middle East, Latin America, South and South-East Asia, Centrally Planned Asia, and Africa.

benefits in the developing and the industrialized world are ambiguous, which is due to different evaluation schemes. The main strand of literature, however, supposes that ancillary benefits are of major importance in developing countries. Nevertheless, it has to considered, that ancillary benefits are a topic of high relevance in highly polluted areas like Santiago de Chile, Mexico City and larger Chinese cities, but are less important in less polluted developing countries like Bolivia or Cuba. Hence, there are wide disparities among developing countries and no unambiguous general result can be derived for the developing world.

Our investigation shows that marginal primary benefits tend to be higher in the developing than in the industrialized world, while the proportions between marginal ancillary benefits in the developing and industrialized world are ambiguous. Consequently, a general assessment of the ratio between marginal primary and marginal ancillary benefits in the developing world compared with the ratio in the industrialized world seems to be hardly feasible.

As an alternative to a cost–benefit consideration, one may assess the perception of problems on the political agenda of countries. A country's marginal propensities to contribute for primary or secondary reasons are likely to depend on the importance of the problems of climate change or regional environmental pollution, respectively, on the political agenda. The developing world's interest in providing GHG control activities is quite limited since the threat of the greenhouse effect is not 'a major priority in the eyes of the DN [DN = developing nations, the author], especially when compared to their laborious economic development, or to the chronic persistence of the famine problem for a certain number of countries' (Rotillon and Tazdaït 1996: 296).[13]

Because of the small budgets that developing countries have to operate with, the willingness of these countries to pay for uncertain future damages is low. The connection between GHG abatement and future benefits is regarded with scepticism, especially in developing countries, 'which must contend today with many urgent problems related to human health and welfare' (Wang and Smith 1999: 3056). In contrast to the developing countries, industrialized countries with larger budgets and already strict local environmental standards have a much greater willingness to pay for the avoidance of future damage.

The latter assessments suggest that the willingness in many developing countries to provide climate protection is mainly motivated by ancillary effects, while the motivation in the industrialized world mainly accrues from the pure public primary effects. Therefore, the differing-abatement-motives argument may dampen the positive effect of transfers from the industrialized countries to the developing world on the global GHG abatement level.

If we allow for the application of technologies which independently produce ancillary or secondary effects, the positive impact of transfers might be further perturbed. On the one hand, industrialized countries could partially offset their loss in the jointly generated private characteristic by raising the independent generation of this characteristic. On

[13] Aunan et al. (2000: 8) point out: 'Whereas the climate change issue may not be given high priority on the political agenda, there is in many developing countries an increasing focus on local and regional pollution problems.'

the other hand, developing countries could reduce their independent production of the jointly generated private characteristic because of the increase in this characteristic's joint production with climate protection. Since the marginal costs of mitigating local externalities tend to be higher in industrialized than in developing countries,[14] the overall independent production of secondary effects would take place in a less efficient way. This would further dampen a positive impact of unconditional transfers on the global GHG abatement level.

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[14] Krupnick (1997: 446) points out that '[w]ith marginal costs of air-pollution abatement generally growing with increasing pollution reductions, developing countries, with lower baseline pollution-abatement activity, are likely to face relatively low marginal abatement costs.'

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