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On Fostering International Public Good Provision: Would Complementarity between Public Good and In-Kind Transfers Help?

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Abstract

A large strand of literature investigates the effects of transfers on the provision of international public goods and on the welfare of donor and recipient. We consider the special case where transfers are conditional on the recipient's contribution to the public good. Transfers take the shape of specific private good transfers which, however, also affect the recipient's benefits from the public good. Public good and in-kind transfers may either be complements or substitutes. As we show, the profitability of adaptation transfers depends only partly on whether the public good and transferred private goods are complements or substitutes. Decisive is rather the strengths of income and substitution effects generated through the transfers.

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1. Introduction

In a world that is characterized by an ever growing interconnectedness, the provision of international public goods becomes increasingly important and the demand for policies that help to alleviate the underprovision of these goods is rising. As a result, a large strand of literature investigates the effects of transfers on the provision of international public goods and on the welfare of donor and recipient. We consider the special case where transfers are conditional on the recipient's contribution to the public good. Transfers take the shape of specific private good transfers which, however, also affect the recipient's benefits from the public good.

The example we focus on is mitigation of and adaptation to climate change. While mitigation is a global public good, adaptation is usually seen as a private good for the implementing region (Barrett 2008). The attention that adaptation receives in the climate policy debate increased considerably since the UN climate summit in 2010 where developed countries pledged 100 billion USD as annual climate-related transfers towards the developing world by 2020. A large share of this sum is expected to go to adaptation and it seems fair to assume that some conditionality might be pending.

There is now a large dispute whether adaptation transfers will help or hinder the attainment of an efficient international climate policy regime. It is sometimes argued that adaptation and mitigation are complements such that adaptation transfers might support efficient climate policy. Complementarity may arise, for example, when adaptation makes mitigation more advantageous, as there will be more valuable assets to be protected in the future. But adaptation and mitigation can also be considered substitutes if adaptation is taken as self-insurance against damages from climate change (see, for example, Auerswald *et al*. 2011).

As we will show the profitability of adaptation transfers depends only partly on whether the public good and transferred private goods are complements or substitutes. Decisive is rather the strengths of income and substitution effects generated through the transfers.

Though considering climate policy, the relevance of our paper is not restricted to this prominent case. Whenever a transfer to one region affects the provision of a good private to this region as well as the benefits from a supra-regional public good, our analysis becomes relevant.

2. Model

In this paper, we employ a similar approach as Pittel and Rübbelke (2013) who focus on substitutability only. The world consists of two regions (a developing region D and a industrialized region I) whose respective incomes $\tilde{I}_i$, $i = I, D$ are given exogenously. Income is spent on public and private good consumption and, in the case of region I, on transfers to region D. Prices are set equal to unity.[1] Both regions' utility depends on the consumption of a private good bundle, y_i, and a global public good 'world-wide mitigation efforts', $X = \sum_i x_i$, with x_i denoting the regional mitigation efforts. The benefits from the private good bundle and the public good both depend on the level of adaptation a_i to climate change.

First, adaptation increases the amount of effective consumption c_i derived from a given private good bundle y_i, that is $c_i = c_i\,(y_i, a_i)$ with $c_{iy_i} > 0$ and $c_{ia_i} > 0$. For the intuition behind this assumption consider the example of reducing the risk from climate change. This can include, for example, developing vaccines or other means to protect the population from diseases that may spread due to the change in the climate (Konrad and Thum 2014) or even provisions like changing crop types to more resistant ones (Kane and Shogren 2000). Second,

[1] The case of differing unit cost is addressed by Pittel and Rübbelke (2013) but is omitted here for reasons of brevity.

the effectively consumable amount of benefits from mitigation X in region i, X_i^c, depends on adaptation, that is $X_i^c = X_i^c(X, a_i)$. Adaptation and mitigation can be complements $\left(\frac{\partial X_i^c}{\partial a_i} > 0\right)$ or substitutes $\left(\frac{\partial X_i^c}{\partial a_i} < 0\right)$. It seems reasonable to assume that adaptation in region i affects the benefits from the private good bundle and from mitigation in region i only. Thus adaptation is a private good from region i's perspective. Keeping the above defined relationships in mind, region i's welfare function is given by

$$U_i = U_i(c_i(y_i, a_i), X_i^c(X, a_i)) \tag{1}$$

where c_i and X_i^c behave like normal 'goods'.
In the following, we assume that only region *I* provides conditional adaptation transfers towards region *D*. As our focus is on the welfare effects of unidirectional international transfers, we abstract from domestic adaptation and transfers towards region *I*.[2]

3. Welfare Maximization and Effective Prices

Region *D* maximizes its welfare function (1) subject to its budget constraint:

$$\max_{y_D, x_D} U_D(c_D(y_D, a_D), X_D^c(X, a_D)) \qquad \text{s.t. } \tilde{I}_D = y_D + x_D. \tag{2}$$

Adaptation transfers from region *I* to region *D* are provided in the form of matching transfers, that is region D's public good provision x_D is matched by the industrialized region in the form of adaptation support $t \cdot x_D$ where $1 > t > 0$ is the so-called matching rate. The monetary transfer tx_D purchases a_D units of adaptation which in turn increases effective private consumption. For simplicity, we assume a linear relationship between effective consumption and its determinants.[3] Setting the price of a_D equal to unity gives $a_D = tx_D$. Effective private consumption is thus given by

$$c_D = y_D + \delta a_D = y_D + \delta t x_D, \tag{3}$$

where $\delta > 0$ measures the 'productivity' of adaptation. Furthermore, we also assume a linear function for X_D^c, that is

$$X_D^c = X + \gamma a_D = X + \gamma t x_D, \tag{4}$$

where $\gamma < 0$ implies substitutability, while $\gamma > 0$ reflects complementarity.
From the first-order conditions of (2) under consideration of (3) and (4), we get

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[2] One could alternatively allow region to have access to good a_D as well, but here it is assumed that it does not pay for *D* to invest in a_D, possibly because the technological knowledge of region *D* is little.

[3] By assuming a linear relationship, we abstract from effects of adaptation on the marginal utility of private goods. Alternatively, we could adopt a multiplicative functional form but both additive and multiplicative depictions have their merits (and weaknesses) in the regarded case of climate policy. There is some room for interpretation and different views, as general empirical results concerning these relationships are not available. So, to keep matters simple, we adopt an additive relationship as it is quite common in the literature on climate change, pollution damages and the environment (see, for example, Pittel 2002 for an overview of papers using this approach as well as, for a more recent example, Hassler *et al*. 2010).

$$\frac{\frac{\partial U_D}{\partial X_D^C}}{\frac{\partial U_D}{\partial c_D}} = \frac{1-\delta t}{1+\gamma t}. \tag{5}$$

(5) shows the trade-off between effectively consumable benefits from mitigation and from the consumption of private goods in the decentralized equilibrium where the policy parameter *t* is given exogenously. The RHS of (5) can be interpreted as the effective price $p_D^e = \frac{1-\delta t}{1+\gamma t}$ of purchasing one unit of X_D^C (in terms of c_D that has to be abandoned in exchange).[4] (5) shows that adaptation transfers have a twofold effect on the effective price: First, 'subsidizing' the public good by raising effective private consumption lowers p_D^e and thus makes investments in mitigation more attractive. Second, whether p_D^e rises or falls due to the effect of adaptation on consumable mitigation depends on $\gamma \gtrless 0$. Given substitutability ($\gamma > 0$), for example, adaptation increases p_D^e which reflects the decreased domestic public mitigation benefits which render mitigation investment less attractive (vice versa for complementarity). We concentrate on scenarios in which the overall effect of the matching rate on the effective price is negative (i.e. $|\gamma| < \delta$ for $\gamma < 0$) such that region *D*'s demand for public good provision will unambiguously rise.[5]

In the following, our focus will be on the effects that matching and changes in the matching rate have on welfare in either region. For some remarks on the optimal matching rate from a global as well as from the industrialized region's perspective, see the Appendix.

4. Comparison of Complementarity and Substitutability Cases

In the following, the welfare effects of transfers are compared for complementarity and substitutability. For this analysis, it is convenient to translate the welfare maximization problem in (1) and (2) into an expenditure minimization problem

$$\min_{y_i, x_i} \; E_i \quad \text{s.t.} \quad U_i(y_i, X) = \overline{U}_i. \tag{6}$$

Capturing all relevant welfare effects of the transfers requires considering not only the private benefits but also the external benefits from the other region's mitigation provision. This can be accomplished by using full income (Cornes and Sandler 1994), i.e. the hypothetical income required for purchasing the amount of all consumed characteristics, including the amount of public characteristics provided by the other region and evaluated at effective prices (or in other words, the monetary income spent on the region's own consumption plus the monetary value of the received externalities):

$$E_I = y_I + p_I^e X - t p_I^e x_D = I_I + x_D, \tag{7a}$$
$$E_D = c_D + p_D^e X^C = I_D + p_D^e x_I \tag{7b}$$

where I_i denotes the income spent on a region's own consumption and $p_I^e = 1$ and $p_D^e = \frac{1-\delta t}{1+\gamma t}$ must be used.[6]

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[4] In the absence of own adaptation but under consideration of transfer payments, region *I* maximizes $U_I(y_I, X)$ subject to $\tilde{I}_I = y_I + x_I + t x_D$ which implies $p_I^e = 1$. As part of the income is spent on adaptation in the other region, the net income available for region *I*'s own consumption is given by $I_I = y_I + x_I = \tilde{I}_I - t x_D$.

[5] To ensure $p_D^e > 0$, we furthermore impose $t\delta < 1$.

[6] For the derivation of (7b) consider that the developing region's full income consists of $E_D = c_D + p_D^e X^C = y_D + x_D t\delta + p_D^e[x_D(1 + t\gamma) + x_I] = I_D - \left(1 - \frac{1-\delta t}{1+\gamma t}(1 + t\gamma) - t\delta\right) x_D + \frac{1-\delta t}{1+\gamma t} x_I = I_D + \frac{1-\delta t}{1+\gamma t} x_I$.

From the first-order conditions of the respective region's optimization problem (6), the compensated demands for the public good $X_i(\overline{U}_i, p_i^e)$ and the optimal expenditure functions $E_i(\overline{U}_i, p_i^e)$ can be derived (see Cornes 1992).
In the global equilibrium, the demand for the public good has to be identical across regions

$$X = X_D(\overline{U}_D, p_D^e) = X_I(\overline{U}_I, 1) \tag{10}$$

and global expenditures will equal global full income

$$p_D^e E_I(\overline{U}_I, 1) + E_D(\overline{U}_D, p_D^e) = p_D^e I_I + I_D + p_D^e X. \tag{11}$$

From (10) and (11), the welfare effects of adaptation transfers on the welfare of the two regions can be derived. The introduction of adaptation transfers will change welfare as well as mitigation levels.
To derive the welfare effects of a change in an existing transfer rate, totally differentiate (10) and (11), rearrange and collect terms (see Ihori 1996) which gives

$$\begin{bmatrix} p_D^e \frac{\partial c_I}{\partial U_I} & \frac{\partial E_D}{\partial U_D} \\ \frac{\partial X_I}{\partial U_I} & -\frac{\partial X_D}{\partial U_D} \end{bmatrix} \begin{bmatrix} dU_I \\ dU_D \end{bmatrix} = \begin{bmatrix} (E_I - I_I)\frac{\delta+\gamma}{(1+\gamma t)^2} - p_D^e x_D \\ -\frac{\partial X_D}{\partial p_D^e}\frac{\delta+\gamma}{(1+\gamma t)^2} \end{bmatrix} dt \tag{12}$$

with $\frac{\partial E_i}{\partial U_i} > 0$, $\frac{\partial X_i}{\partial U_i} > 0$, $\frac{\partial X_D}{\partial p_D^e} < 0$, $E_I - I_I = x_D$ and where $c_I(U_I, p_I^e)$ is the compensated demand function for private consumption in region I (with $\frac{\partial c_I}{\partial U_I} > 0$). Applying Cramer's rule gives the welfare effects of changes in t that we are looking for.

4.1 Effects on Region I's Welfare

For region I we obtain from (12)

$$\frac{dU_I}{dt} = \underbrace{\left[p_D^e - \frac{\delta+\gamma}{(1+\gamma t)^2}\right]\frac{x_D \frac{\partial X_D}{\partial U_D}}{\Delta}}_{TIE^I} + \underbrace{\frac{\delta+\gamma}{(1+\gamma t)^2}\frac{\frac{\partial X_D}{\partial p_D^e}\frac{\partial E_D}{\partial U_D}}{\Delta}}_{SPE^I}, \tag{13}$$

where $\Delta = -\left(p_D^e \frac{\partial c_I}{\partial U_I}\frac{\partial X_D}{\partial U_D} + \frac{\partial E_D}{\partial U_D}\frac{\partial X_I}{\partial U_I}\right) < 0$. TIE^I represents the total income effect of a change in t and SPE^I gives the corresponding substitution price effect. Under the assumptions made, SPE^I is unambiguously positive. The sign of TIE^I, however, depends on γ as well as on the policy variable, t, and the productivity of adaptation, δ. Given the focus of the paper, our interest is mainly in γ.
Note first that a strong reaction of public good provision to adaptation – may mitigation and adaptation be complements or substitutes – reduces the chances of in-kind transfers to have a beneficial welfare effect for region I, ceteris paribus. For $\gamma \to \infty$, an unrealistic but instructive example for a high degree of complementarity, SPE^I converges to zero while TIE^I becomes negative. Put it differently, X_D^c becomes so large that contribution x_D is lowered. For a high degree of substitutability (take $|\gamma| \to \delta$ for $\gamma < 0$), exactly the same happens. In this case, the effective price p_D^e approaches the pre-transfer price of unity, so that transfers have no effect on the provision of x_D.

What about the policy implications of complementarity and substitutability? Assume first that mitigation and adaptation are complements ($\gamma > 0$). In this case, the lower the matching rate, the higher the policy induced welfare effect as SPE^I rises and TIE^I becomes at least less negative (it might even turn positive) In the case of substitutes ($\gamma < 0$), the policy implications are, however, exactly opposite. Now, choosing a higher t will raise TIE^I as well as SPE^I. So, at least for the transfer paying region, the question of whether the private and the public good are complements or substitutes is crucial for policy recommendations.

4.2 Effects on Region D's Welfare

Although the expression that describes the welfare effect of a change in t in region D

$$\frac{dU_D}{dt} = \underbrace{\left[p_D^e - \frac{\delta+\gamma}{(1+\gamma t)^2}\right] \frac{x_D \frac{\partial X_I}{\partial U_I}}{\Delta}}_{TIE^D} - \underbrace{\frac{(\delta+\gamma)}{(1+\gamma t)^2} \frac{\frac{\partial c_I}{\partial U_I} \frac{\partial X_D}{\partial p_D^e}}{\Delta}}_{SPE^D}, \qquad (14)$$

looks similar to (13), the differences between the two expressions are important. First, SPE^D and SPE^I are always of opposite sign, such that changes in the parameters that raise the welfare increase from the substitution effect for region I result in a corresponding increase in the welfare loss for region D. With respect to the total income effect, however, the effect of a change in t is always of the same sign for both regions. Consequently, a policy design that results in a higher TIE^I will also raise TIE^D. If, for example, mitigation and adaptation are complements ($\gamma > 0$) and region I lowers t, this will raise the TIE in both regions and also increase SPE^I. Simultaneously, however, SPE^D becomes more negative. So, for region D a trade-off arises. In the case of substitutes ($\gamma < 0$), a rise in t will induce qualitatively the same effects. Whether or not a policy that increases welfare in region I will accomplish the same for region D, thus depends on the strength of income and substitution effects.

5. Conclusions

From the above analysis we can draw two main conclusions: 1. Whether or not a private good, whose provision is fostered by interregional conditional transfers, and a supra-regional public good, whose benefits are affected by these transfers, are complements or substitutes matters to a large extent for the induced welfare and policy effects. 2. However, more important for the transfers' potential to improve on the welfare of both regions (transfer-paying and -receiving) are the strengths of income and substitution effects.
Thus, in the context of international in-kind adaptation transfers, the discussion about complementarity/substitutability between mitigation and adaption is too narrowly considered. If the interdependencies between transferred private goods and the public good are not carefully taken into account, transfers bear a high risk of being harmful for some agents and may threaten the attainment of a Pareto-improved outcome. Like in other contexts, positive intentions may bring about undesired results.

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Appendix: Optimal Adaptation and Matching Rates

In the following, we shortly consider mitigation and adaptation in the global optimum (first-best equilibrium). We then show that the matching scheme applied here can only lead to a second-best equilibrium and calculate the corresponding matching rate. Finally, we take a look at the optimal choice of *t* from the perspective of the industrialized region.

Assuming that global welfare is given by the sum of the regions' individual welfare, the maximization problem from the perspective of a global planner reads

$$\max_{y_D, x_D, y_I, x_I, a_D} U_D(y_I, X) + U_D(c_D(y_D, a_D), X_D^c(X, a_D)) \text{ s.t. } \tilde{I}_I + \tilde{I}_D = y_I + x_I + y_D + x_D + a_D.$$

From the first-order conditions we get

$$\frac{\partial U_I}{\partial y_I} = \frac{\partial U_D}{\partial c_D}\frac{\partial c_D}{\partial y_D} = \frac{\partial U_I}{\partial X} + \frac{\partial U_D}{\partial X_D^c}\frac{\partial X_D^c}{\partial X} = \frac{\partial U_D}{\partial c_D}\frac{\partial c_D}{\partial a_D} + \frac{\partial U_D}{\partial X_D^c}\frac{\partial X_D^c}{\partial a_D} \qquad \text{(A1)}$$

which shows that in the global optimum, the marginal utilities from private goods, mitigation and adaptation have to be the same across both regions. Substituting $X_D^c = X + \gamma a_D$ and $c_D = y_D + \delta a_D$ from (3) and (4), the above expression (A1) simplifies to

$$\frac{\partial U_I}{\partial y_I} = \frac{\partial U_D}{\partial c_D} = \frac{\partial U_I}{\partial X} + \frac{\partial U_D}{\partial X_D^c} = \frac{\partial U_D}{\partial c_D}\delta + \frac{\partial U_D}{\partial X_D^c}\gamma$$

From this we get two conditions for the optimal provision of the public good, mitigation, and the private goods, adaptation and consumption:

$$\frac{\frac{\partial U_I}{\partial X}}{\frac{\partial U_I}{\partial y_I}} + \frac{\frac{\partial U_D}{\partial x_D^c}}{\frac{\partial U_D}{\partial c_D}} = 1 \qquad \text{and} \qquad \frac{\frac{\partial U_I}{\partial X}+\frac{\partial U_D}{\partial x_D^c}}{\frac{\partial U_D}{\partial c_D}\delta+\frac{\partial U_D}{\partial x_D^c}\gamma} = 1$$

The condition on the LHS is the well-known Samuelson condition; the condition on the RHS states basically the same, only in this case with respect to the private good adaptation. The first-order conditions plus the budget constraint determine the social optimum allocation of private and public goods.

The first-best optimum can, however, not be attained by employing the proposed matching mechanism, as mitigation and adaptation cannot be chosen independently anymore. Assuming that a global planner only has the matching mechanism at its disposal to implement the adaptation transfer, the matching rate in the second-best optimum can be obtained from the above maximization problem by substituting $a_D = tx_D$ and optimizing over t instead of a_D. This gives, after some manipulation of the first-order conditions, the marginal rate of substitution between effective benefits from private goods and mitigation in the second-best equilibrium

$$\frac{\frac{\partial U_D}{\partial x_D^c}}{\frac{\partial U_D}{\partial c_D}} = \frac{1-\delta}{\gamma}.$$

However, in the real world no global regulator exists that can enforce any t whether it is second-best or not. Considering this, let us take a look at the optimal t from the industrialized country's perspective where region I is aware of the reaction of region D's mitigation to the adaptation transfer. The industrialized country faces the following maximization problem:

$$\max_{y_I, x_I, t} \; U_I(y_I, X) \quad \text{s.t.} \quad \tilde{I}_I = y_I + x_I + tx_D.$$

From the first-order conditions we get

$$\frac{\partial U_I}{\partial y_I} = \frac{\partial U_I}{\partial X} = \frac{\frac{\partial U_I}{\partial X}\frac{\partial x_D}{\partial t}}{x_D + \frac{\partial x_D}{\partial t}t}.$$

This implies that region I will raise t to a level, where the marginal benefit of conducting a unit of own mitigation is equal to the marginal benefit of manipulating the mitigation of region D. This implies an optimal matching rate of $t = 1 - \frac{x_D}{\frac{\partial x_D}{\partial t}t}$. As intuition suggests, the matching rate will be the higher, the stronger the marginal effect on mitigation in region D.