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Strategic transfers and private provision of public goods

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Abstract

This paper considers strategic monetary transfers between two agents when these contribute to a mutual public good. If the agents differ in their contribution productivity, then the less productive agent has an incentive to make large unconditional transfers to the more productive agent. Although agents move simultaneously in each stage of the game, the less productive agent becomes a Stackelberg leader. Furthermore, the generic subgame perfect equilibrium is characterized by full specialization.

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1. Introduction

In the standard model of private provision of a public good[1] the distribution of incomes among contributors is irrelevant for the equilibrium

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[1] Some standard references are Andreoni (1988), Bergstrom et al. (1986), Cornes and Sandler (1985, 1986), McGuire (1974), and, for an application to international transfers, Kemp (1984).

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allocation of goods (Warr, 1982, 1983). Therefore transfers among contributors prior to the contribution decisions are neutral. This strong neutrality result rests on the assumption that all contributors face the same price for increasing the amount of the public good.

Often contributors may face different 'prices' of adding an additional unit of money to the sum of contributions, or may have different productivities of enhancing the aggregate amount of the public good. When money is sent to a common agency that produces the public good, a unit of money received by the agency may cost the contributors different amounts. For instance, contributions to a public good may be tax deductible and potential contributors may have different tax rates.[2] But different productivities in contributing to a public good may also occur when agents contribute to the public good directly. Examples in an international context are cross-border pollution and safety risks of nuclear power plants. The importance of international environmental issues has been highlighted, e.g. by Carraro and Siniscalco (1991). Suppose two countries share an environmental good. Their abatement activities may affect environmental quality in an additive way (Hoel, 1991). Their unit cost of abatement may differ, since they typically use different technologies. Another example is radiological protection. Consider two nuclear power plants at the border between two countries, say Germany and Poland, each country managing one plant. Both countries are exposed to similar contamination risks. Typically, if the countries do not cooperate and have different income levels, they choose different safety standards for their own plant. With safety technologies with increasing marginal cost, choosing a marginally lower *overall* accident probability would have been cheaper for the country that applies that lower safety standard to its plant.[3] The theory of private provision of a public good is particularly relevant here, since maintenance effort and care is difficult for neighboring countries to observe and, hence, cooperation is difficult. Other examples can be found in international politics, when two countries pursue the same goal vis-à-vis a third country, for instance stabilizing this country politically. For historical or political reasons, it may be much easier (less expensive) for one of the countries to achieve this goal.

[2] Differing tax rates may not lead to non-neutrality if tax proceeds are redistributed among contributors, or if government contributes additional tax proceeds to the public good. For neutrality results in this case, see Boadway et al., (1989), Andreoni and Bergstrom (1992) and Glazer and Konrad (1993). However, neutrality breaks down, and the results in this paper apply, if government expenditure does not affect the contributor's decision problem.

[3] Suppose countries 1 and 2 choose different accident probabilities p_1 and p_2, with $p_1 < p_2$, leading to an overall probability of $p \equiv p_1 + p_2 - p_1 p_2$ (independent accident risks assumed) for contamination of the region. A lower overall probability p is achieved by smaller p_1 or p_2, but if both countries have the same technology with increasing marginal safety cost, it is cheaper to achieve this goal by the choice of a smaller p_2.

This paper considers the strategic role of monetary transfers between potential future contributors to a public good in such situations. We keep the assumption made in the standard model that contributions to the public good sum up, but we allow for agents having different productivities in contributing.[4] We consider two agents (countries) who have given incomes that can be used for private consumption or for contributions to a pure public good. We exclude binding contracts or cooperative behavior and consider the subgame perfect outcome. It turns out that a country with a low productivity has an incentive to make large unconditional transfers to the other country. Even though the transfer is unconditional, i.e. the recipient does not make any promise in lieu of the transfer received, the donation yields an equilibrium outcome that is Pareto superior. Both gain. Moreover, the subgame perfect equilibrium always has full specialization. If positive transfers occur in equilibrium, then specialization is according to comparative advantage.

Incentives to make unconditional transfers in a world without altruism have been identified in some other situations, e.g. in the literature on strategic transfers in international trade theory (Gale, 1974; Bhagwati et al., 1983) and also in Ihori's (1992) impure public good model, where the beneficial effect for the donor depends on the existence of a third party.[5] A distinguishing feature here is that the transfer that is induced by the prospect of a game of private provision of a public good is generally beneficial for all parties involved.

Our model is closest to Vicary (1990) who analyses transfers in Hirshleifer's (1983) 'weakest link' model.[6] Hirshleifer considers a case in which contributions by individuals do not sum up to the aggregate amount of the public good. Instead, the amount of the public good provided is equal to the amount of provision by the contributor who makes the smallest contribution. The very rich may want to make transfers to the very poor to stimulate higher contributions by the poor. Vicary shows that, from the perspective of the rich, such transfers to the poor are a public good itself. Hence, there is a free-rider problem within the group of rich agents. Redistribution neutrality, particularly within the group of donors, may result, even in Hirshleifer's non-linear model.

[4] Contributions are in money. However, the model would also apply if agents contribute amounts of some physical good (e.g. time) for which they have different opportunity cost.

[5] The central mechanism in strategic trade theory is that the transfer has income effects that change the terms of trade in a way favorable for the donor and the benefits of the terms of trade effects overcompensate the income reduction experienced by the transfer.

[6] For an important generalization of this model, see Cornes (1993). See also Bliss and Nalebuff (1984) for a different (best shot) production function for the public good.

Our paper considers only two agents (countries). Hence, Vicary's free-rider problem does not arise. Indeed, Hirshleifer's 'weakest link' technology of provision of the public good would make the transfer problem in our paper straightforward. Instead, in this paper the aggregate amount of the public good is a continuous function of both individual's contributions, as in the standard model. In contrast to Vicary, and also to the standard model, the transfer problem is generated by an asymmetry in terms of global productivity of public good contribution. Transfers are an expensive way of increasing the amount of the public good. In practice, agents will try to make agreements to overcome this problem. But in many situations such agreements are not feasible.

The paper proceeds as follows. Section 2 outlines the model and considers briefly the non-cooperative Nash equilibrium of voluntary contributions to a pure public good when all transfers have already been made. Section 3 characterizes the relationship between income distribution and the resulting Nash equilibrium. Section 4 considers transfers at a stage prior to the voluntary provision game. This section presents the main results of the analysis. Section 5 concludes.

2. The model

We consider a model with two agents, $i = 1, 2$. For concreteness we will consider them to be countries with benevolent governments acting on behalf of their citizens. Each country maximizes a strictly increasing and strictly quasi-concave utility function

$$u^i(y_i, G)\,, \tag{1}$$

where y_i is the amount of a private good consumed by country i, and

$$G \equiv g_1 + g_2 \tag{2}$$

is the sum of countries' contributions to a pure public good, i.e. a good that is non-rival between the two countries. Generally, the costs of contributing to such public goods are different for the two countries. Country i has to give up c_i units of private good consumption for each unit it contributes to the public good, or, equivalently, country i can contribute $s_i = 1/c_i$ units to the public good by spending one unit less on private consumption. We will refer to c_i as i's marginal cost of contributing, and to s_i as i's productivity parameter and assume that they are constant.

The two countries have exogenous initial endowments m_i in units of the private good so that aggregate endowment of the economy is $M = m_1 + m_2$.

The endowments can be consumed, transformed into a contribution to the public good, or donated to the other country, in which case the other country's endowment increases by this transfer. We will consider the following time structure of actions. First, at stage 1 countries decide simultaneously whether they want to give a non-negative transfer to the other country, where t_i is the transfer from country i to the other. The resulting post-transfer incomes are $\mu_1 \equiv m_1 + t_2 - t_1$, and $\mu_2 \equiv m_2 + t_1 - t_2$.

In a later stage (stage 2), both countries choose their contributions to the public good.[7] We assume non-cooperative Nash behavior and look for the subgame perfect equilibrium. Solving backwards, we first describe stage 2 of the game when both countries determine their contributions to the public good for given transfers.

The Nash equilibrium at stage 2 is characterized by contributions g_1 and g_2 and, hence, amounts of private consumption

$$y_i = \mu_i - c_i g_i \quad \text{for } i = 1, 2 , \tag{3}$$

so that, for given contributions by the other country, country i's choice, g_i, maximizes its utility (1) subject to (2) and (3). A short-hand notation for this equilibrium is (y_1^*, y_2^*, G^*).

An *interior equilibrium*, in which both countries make strictly positive contributions, is described by the marginal conditions

$$MRS^i_{G,y_i} \equiv \frac{u^i_G(y_i^*, G^*)}{u^i_y(y_i^*, G^*)} = \frac{1}{s_i} \quad \text{for } i = 1, 2 . \tag{4}$$

Here, $u^i_y(y_i, G)$ and $u^i_G(y_i, G)$ denote country i's marginal utility of consumption of the private and of the public good. Each country chooses an aggregate amount of the public good that equates its ratio of marginal utilities of private and public consumption to its productivity parameter. This equilibrium condition is well understood, e.g. from Cornes and Sandler (1986).

An equilibrium with a *corner solution* for one of the countries – say country 1 – is described by $y_1^* = \mu_1$, $y_2^* = \mu_2 - c_2 G^*$, where, for country 2, (4) holds for (y_2^*, G^*), and, for country 1, $u^1_G(\mu_1, G^*)/u^1_y(\mu_1, G^*) \leq 1/s_1$ (see Bergstrom et al., 1986).

We follow a standard assumption in the theory of private provision of a public good and assume that, for both countries, both the private and the public goods are strictly superior everywhere. For given s_i, the income

[7] As suggested by a referee, countries may make their contribution decisions one after the other at stage 2. A Stackelberg game of private provision of a public good leads to amounts of provision different from the Nash outcome, but it has similar properties with respect to income redistribution. Indeed – without proof here – an incentive for large transfers can also occur.

consumption curve of country i is the locus of all combinations of private consumption y_i and public good G in the y_i–G plane in which the marginal rate of substitution of country i between its private consumption and the consumption of the public good equals the country's productivity parameter. Given the superiority of both goods, the income consumption curve can be written as a bijective function,

$$y_i = h^i(G, s_i)\,, \tag{5}$$

with strictly positive slope everywhere. Obviously, there is a set of income consumption curves, one for each productivity parameter. We can now state

Proposition 1. The Nash equilibrium for given post-transfer incomes is unique.

Proof. First we show by contradiction that the equilibrium amount of aggregate contributions is unique. Suppose G^1 and G^2 are two different equilibrium amounts, with $G^1 > G^2$. In equilibrium with aggregate provision G^1, at least one country, i, contributes a positive amount larger than in the equilibrium with aggregate provision G^2. Hence, for this country private consumption

$$y_i^1 < y_i^2$$

by the country's budget constraint. But

$$y_i^1 = h^i(G^1, s_i) > h^i(G^2, s_i) \geq y_i^2$$

by the monotonicity of the income consumption curve. This is a contradiction. Hence, the equilibrium amount of aggregate contributions is unique.

Now we show that the aggregate amount of the public good uniquely determines individual contributions and private consumption. Define $\overline{G}_i$ as the amount of the public goods that fulfills $\mu_i = h^i(\overline{G}_i, s_i)$. By the monotonicity of h^i, for any equilibrium amount of the public good $G^* \geq \overline{G}_i$, country i contributes zero. For any $G^* < \overline{G}_i$, country i's private consumption in equilibrium is determined by $y_i^* = h^i(G^*, s_i)$, and its contribution to the public good is $g_i^* = s_i(\mu_i - y_i^*)$. Therefore G^* uniquely determines the contributions g_1^* and g_2^*. □

Proposition 1 generalizes uniqueness to the case with differing productivity parameters and is shorter than the ones by Bergstrom et al. (1986, 1992) and by Fraser (1992).

3. Non-neutrality of income redistribution

By Proposition 1, for each pair of post-transfer incomes (μ_1, μ_2) there is a unique equilibrium. We will first consider the set of interior equilibria. Summing the constraints (3) for $i = 1$ and 2, using (2) and by some straightforward manipulations we obtain a necessary feasibility constraint, $s_1\mu_1 + s_2\mu_2 = s_1 y_1 + s_2 y_2 + G$. Substitution of (5) yields

$$s_1\mu_1 + s_2\mu_2 = G^* + s_1 h^1(G^*, s_1) + s_2 h^2(G^*, s_2) . \tag{6}$$

Since all terms on the right-hand side of (6) are continuous and strictly increasing in G^*, Eq. (6) implicitly determines the equilibrium as a function of μ_1 and $\mu_2 = M - \mu_1$. For $s_1 = s_2$, the value of G^* that solves (6) is independent of how aggregate income M is shared between μ_1 and μ_2, which is the well-known redistribution invariance result in the theory of private provision of public goods (Warr, 1983; Kemp, 1984). Eq. (6) also reveals that redistribution invariance fails to hold for differing productivity parameters. For $s_1 \neq s_2$, redistribution changes the sum $s_1\mu_1 + s_2\mu_2$ and, hence, G^* that fulfills (6).

We give now a full characterization of the Nash equilibrium outcomes for different pairs (μ_1, μ_2) for given aggregate income $M = \mu_1 + \mu_2$, including corner solutions. We assume $s_2 > s_1$, i.e. country 2 is more cost efficient in producing the public good. We consider the mapping

$$\begin{aligned} \Phi &: [0, M] \to \mathbb{R}_+ \times \mathbb{R}_+ \times \mathbb{R}_+ , \\ &\mu_1 \to (y_1^*, y_2^*, G^*) , \end{aligned} \tag{7}$$

which maps the interval of feasible incomes of country 1, $\mu_1 \in [0, M]$, into the space of possible equilibrium outcomes, (y_1^*, y_2^*, G^*). The equilibrium outcomes are depicted in Fig. 1 and can be explained as follows. Suppose $\mu_1 = M$, i.e. total aggregate income falls to country 1. The equilibrium is characterized by points (A, A') in Fig. 1. Country 1 chooses G^A and $y_1^A \equiv h^1(G^A, s_1)$ determined by

$$G^A + s_1 h^1(G^A, s_1) = s_1 M , \tag{8}$$

that is, a combination of private consumption and public good provision G^A on its income consumption curve that just exhausts its income M. Country 2 obtains the same amount of the public good, but, of course, has no private consumption.

If μ_1 falls, μ_2 increases. But for μ_2 sufficiently low, country 2 still does not contribute in the Nash equilibrium, since $h^2(g_1, s_2) > \mu_2$, where g_1 is defined by $h^1(g_1, s_1) = \mu_1 - c_1 g_1$. Hence, the equilibrium is characterized by a downward move on country 1's income consumption curve. This move

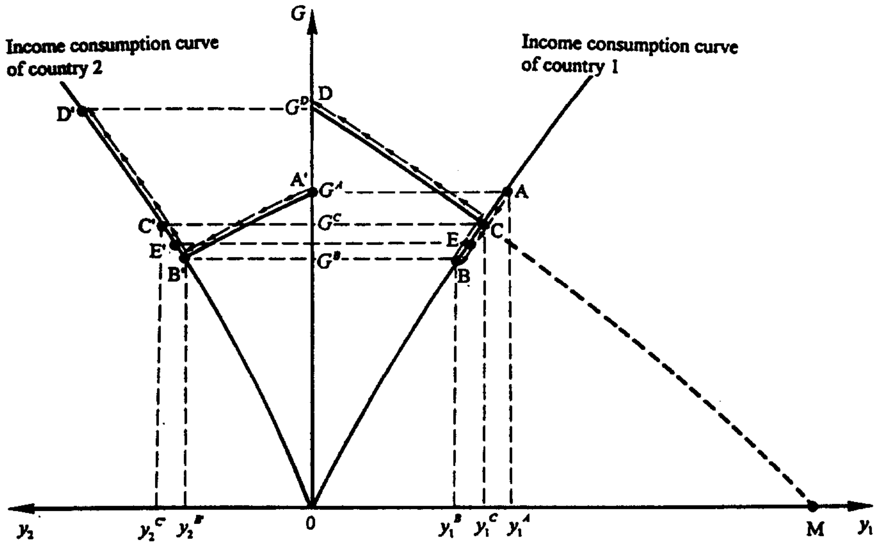


Fig. 1.

continues along $AB\,(A'B')$ until, at $B\,(B')$, μ_2 is so large in comparison with μ_1 that, for a further decrease (increase) in $\mu_1(\mu_2)$ country 2 starts contributing. More precisely, at point $B(B')$, $g_2 = 0$ and $y_2 = \mu_2$, but, by (6),

$$s_1[M - h^2(G^B, s_2)] + s_2 h^2(G^B, s_2) = G^B + s_1 h^1(G^B, s_1) + s_2 h^2(G^B, s_2)$$

or

$$G^B + s_1(h^1(G^B, s_1) + h^2(G^B, s_2)) = s_1 M\,. \tag{9}$$

A comparison between (8) and (9) yields $G^A > G^B$, since, by normality, h^1 and h^2 are strictly increasing in G.

For lower μ_1 (and higher μ_2) than in $B(B')$ both countries contribute positive amounts to the public good. Of course, this implies that both countries reach a position on their income consumption curve in equilibrium. In an interior equilibrium a decrease in μ_1 makes the equilibrium in Fig. 1 move outward along the income consumption curve of country 1 (and country 2). The argument goes as follows. Suppose μ_1 is decreased by a marginal unit. This transfer increases the left-hand side of (6) by $s_2 - s_1$. To restore equilibrium, the right-hand side has to increase. As the right-hand side of (6) is strictly increasing in G, this can be achieved only by increasing the amount of the public good. But $y_1^* = h^1(G^*, s_1)$ is strictly increasing in G^* and, therefore, y_1^* must also increase.

The move outside along country 1's income consumption curve continues as long as the decrease in μ_1 (and increase in μ_2) still generates an interior equilibrium. The equilibrium outcomes in this range are described by the segment BC in Fig. 1 for country 1, and by $B'C'$ for country 2. There is a critical level of μ_1 from which point on country 1 becomes a non-contributor. The equilibrium value of the public good for which this point is reached is G^C and is defined by

$$G^C = s_2[M - \mu_1 - h^2(G^C, s_2)] \tag{10}$$

and

$$\mu_1 = h^1(G^C, s_1)\,, \tag{11}$$

or, equivalently,

$$G^C + s_2(h^1(G^C, s_1) + h^2(G^C, s_2)) = s_2 M\,. \tag{12}$$

The left-hand side of (12) is strictly increasing in G. Since $s_2 > s_1$, we get by comparing (9) and (12) that $G^B < G^C$.

Once μ_1 is so small that country 1 does not contribute to the public good, this is also true for a distribution with even lower μ_1. The equilibrium outcomes in which country 1 does not contribute to the public good are described by the curve from point $C\,(C')$ to point $D\,(D')$ in Fig. 1, where, along this curve, μ_1 decreases. The curve CD starts in $(h^1(G^C, s_1), G^C)$ and its slope is determined by

$$\frac{\mathrm{d}G}{\mathrm{d}y_1} = -s_2 \Big/ \left[1 + s_2 \frac{\mathrm{d}}{\mathrm{d}G} h^2(G, s_2)\right]. \tag{13}$$

The curve MD is the locus of all points (y_1, G) that country 1 would achieve for different income levels μ_1 if it could credibly commit not to contribute to the public good in stage 2. For $y_1 = \mu_1 = M$ (and, hence, $\mu_2 = 0$) country 2 does not provide anything to the public good. For smaller $y_1 = \mu_1$, the distance between M and y_1 measures country 2's income and the curve MD determines how much income country 2 uses to provide the public good. Hence, for increasing income μ_2 from the right to the left, MD is country 2's Engel curve with its origin in M. But only the segment CD of MD describes Nash equilibria. A point on MC would not be compatible with the Nash conjecture; given country 2's contribution, country 1's best response would be to provide more than zero.

Along CD, by transferring an addition unit of income to country 2, country 1 reduces its private good consumption by one unit and increases country 2's income by this unit. The slope of country 2's Engel curve along CD determines how much of this additional income is spent on the public good. The graph of the function Φ ends at point $D\,(D')$. This point represents the Nash equilibrium in which country 2 has the whole income. The amount of the public good provided by country 2 is G^D and is determined by

$$G^D + s_2 h^2(G^D, s_2) = s_2 M \,. \tag{14}$$

The amount of private good consumption by country 1 is $y_1 = 0$.

4. Strategic transfers

The description of the non-cooperative Nash equilibrium for different share-outs of aggregate wealth between the countries can be used to determine countries' incentives to make transfers in units of the private good at a stage (stage 1) prior to the actual contribution game. Of course, we only allow for non-negative transfers $t_i \geq 0$ for $i = 1, 2$. The following property holds.

Proposition 2. For $s_2 > s_1$, country 2 makes zero transfers.

Proof. Suppose that country 2 makes a positive transfer $t_2 > 0$. First consider the case where country 2 makes positive contributions to the public good at stage 2. Country 2's position is on the segment $B'D'$ of its income consumption curve in Fig. 1. A reduction in t_2 increases μ_2 (and decreases μ_1) by the same amount, and makes country 2 move up its consumption curve. Thus, the reduction in the transfer increases country 2's utility. Now let country 1 be the only contributor. The equilibrium is on the segment AB ($A'B'$). Consider a marginal reduction in t_2 to $t_2 - \mathrm{d}t_2$, with $\mathrm{d}t_2 > 0$. If the equilibrium was exactly in (B, B'), the same argument as in the case with positive contributions of country 2 applies. If the equilibrium is bounded away from (B, B'), then a marginal reduction in t_2 moves the equilibrium slightly toward $B(B')$, but country 2 still does not contribute. Country 2's private consumption then increases by $\mathrm{d}y_2 = \mathrm{d}t_2$. Country 1's post-transfers income decreases by $-\mathrm{d}t_2$. By normality, the decrease $-\mathrm{d}\mu_1 = -\mathrm{d}t_2$ makes country 1 decrease both private consumption and public goods provision. Now, $-\mathrm{d}y_2 = -\mathrm{d}t_2 = -\mathrm{d}\mu_1 = -(\mathrm{d}y_1 + c_1\,\mathrm{d}G) < -c_1\,\mathrm{d}G$ such that $\mathrm{d}y_2/\mathrm{d}G > c_1$. But $c_1 > c_2 > MRS^2_{G,y_2}$. Therefore, lowering transfers by country 2 increases y_2 by more than enough to compensate country 2 for the decrease in G. Thus country 2 would want to lower any positive transfer in this case too. Hence, it never makes a positive transfer. □

Proposition 2 simplifies the analysis. As country 2 always chooses $t_2 \equiv 0$, by its choice of transfer t_1, country 1 determines the combination of post-transfer incomes, and, by Proposition 1, the equilibrium values of private and public good consumption. Country 1 will choose the equilibrium that yields the highest attainable utility, $u^{1*}(y_1, G)$. Suppose that points (E, E') in Fig. 1 characterize the Nash equilibrium in the absence of transfers, i.e. for $\mu_i \equiv m_i$. Country 1 cannot choose among all points on the graph Φ. It cannot make negative transfers. Only the segment ECD is achievable for it. In principle, point E can be any point along $ABCD$.

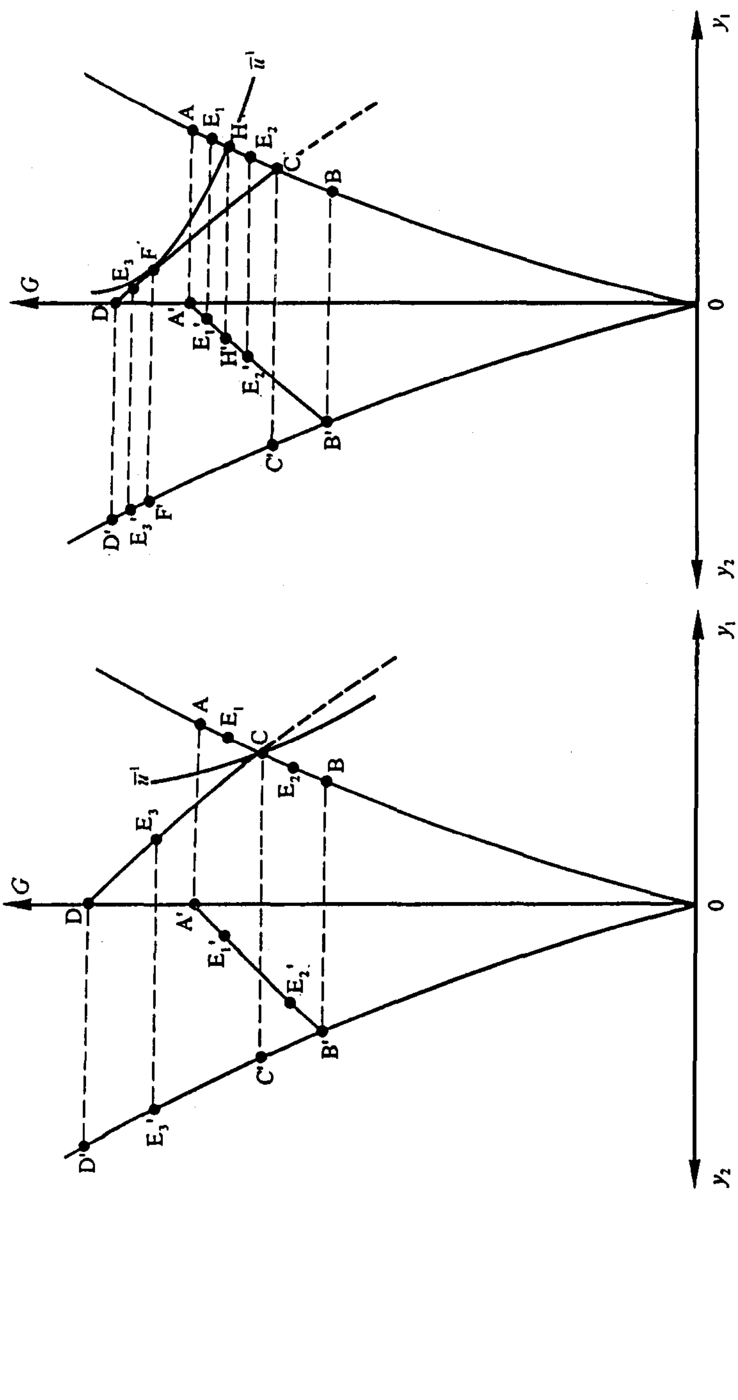
Figs. 2(a) and 2(b) characterize country 1's possible choices. In Fig. 2(a) the interior equilibrium $C\,(C')$ in which country 1 just stops being a contributor is better for country 1 than every other solution in which only country 2 makes a positive contribution to the pure public good. If the initial income distribution without transfers were to lead to an equilibrium in (E_2, E_2'), country 1 can reach $C(C')$ by an appropriate transfer to country 2. A transfer that yields equilibrium (C, C') instead of (E_2, E_2') is welfare-enhancing for both countries. The optimal transfer, $t_1^* = m_1 - h_1(G^C, s_1)$, yielding an equilibrium in (C, C') is implicitly determined by (10) and (11). By this argument, all points along CBC can be ruled out as equilibria.

If the initial income distribution were to lead to an equilibrium in (E_1, E_1') without transfers, then country 1 would choose zero transfers. That is, (E_1, E_1') is a subgame perfect equilibrium. If the initial income distribution without transfers leads to an equilibrium (E_3, E_3'), country 1 can choose among the equilibria along DE_3. The curve DE_3 can have any monotonic negative slope. Some points to the left of E_3 may yield higher utility than E_3, in which case positive transfers occur.

In Fig. 2(b) (F, F') is the subgame perfect equilibrium that country 1 chooses for any initial distribution of incomes that, without transfers, would lead to equilibria along $HBCF$ $(H'B'C'F')$. For the segments AH and FD arguments identical to those for Fig. 2(a) apply: if country 1's initial endowment without transfers yielded a stage-2 equilibrium (E_1, E_1') to the right of H, it would not want to make positive transfers, and, for points (E_3, E_3'), we cannot rule out positive transfers being in country 1's interest. As the general shape of country 2's Engel curve is not necessarily concave, it is not clear that there is no equilibrium to the left of E_3 which country 1 prefers to (E_3, E_3'). Increases in transfers that shift the equilibrium from (C, C') towards (F, F') can be seen as an 'exchange', where country 1 effectively 'pays' country 2 for providing additional quantities of the public good.

A sufficient condition for country 1 to prefer some point F along CD to C is that the indifference curve at C is flatter than the curve CD at point C. By (13), this is true if

$$s_1 < \frac{s_2}{1 + s_2 \dfrac{dh^2(G^C, s_2)}{dG}}, \tag{15}$$


G
D
A
E1
H
E2
C
B
F
E3
A'
E1'
H'
E2'
B'
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E3'
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y2
G
D
A
E1
C
E2
B
E3
A'
E1'
E2'
B'
C'
E3'
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0
y1
y2

Fig. 2.

or, equivalently,

$$c_1 > c_2 + \frac{d}{dG} h^2(G^C, s_2) .$$

The left-hand side in (15) is equal to the absolute value of the slope of country 1's indifference curves along its income consumption path. The right-hand side is equal to the slope of country 2's Engel curve for the public good in G^C.

After these considerations we summarize the central results.

Proposition 3.

(i) *In every subgame perfect equilibrium with $s_1 \neq s_2$, one and only one country makes positive contributions to the public good.*

(ii) *If the Nash equilibrium in a one-stage game for zero transfers (i.e. for $m_1 \equiv \mu_1, m_2 \equiv \mu_2$) were an interior equilibrium, then only the more productive country would provide the public good in the subgame perfect equilibrium of the two-stage game.*

Condition (ii) specified in Proposition 3 leading to full specialization on public good provision of the more productive country is overly restrictive. For instance, if in Fig. 2(b) the no-transfers equilibrium is E_2 between C and H, country 1 has an incentive to make a positive transfer to achieve equilibrium F in which country 2 specializes on public good provision. Only in a situation like E_1 in Figs. 2(a) and 2(b) there is a subgame perfect equilibrium with the less productive country as the only contributor. If $G^C > G^A$, this case is impossible, regardless of the initial distribution of income. Since $h^1(G, s_1)$ and $h^2(G, s_2)$ are strictly increasing in G by (12), this condition is equivalent to

$$c_2 G^A + h^1(G^A, s_1) + h^2(G^A, s_2) < M ,$$

or, since by (8) $h_1(G^A, s_1) = M - c_1 G^A$, we get a further sufficient condition for full specialization on private provision by the more productive country.

Proposition 4. Any initial distribution of income yields a subgame perfect equilibrium in which only the more productive country contributes to the public good if

$$h^2(G^A, s_2) < (c_1 - c_2) G^A \tag{16}$$

holds.

Condition (16) in Proposition 4 states that, for C to be above and to the right of A, the required private good consumption that makes country 2 willing to provide $g_2 = G^A$ must be smaller than the production cost savings if country 2 provides the quantity G^A instead of country 1.[8]

By (16), an income transfer that makes country 2 specialize in public good provision is more favorable for country 1 if country 2 does not use a large fraction of this transfer for private good consumption, i.e. if $h^2(G, s_2)$ is small. Alternatively, if $h^2(G, s_2)$ is large, country 2's tastes are biased more in favor of the private good. A subgame perfect equilibrium in which the less productive country 1 provides the public good (like in G^A) is more likely. Furthermore, suppose that c_1 and hence, G^A is fixed and consider a decrease in c_2. Then the left-hand side of (16) decreases. Country 2's income consumption curve bends inwards, i.e. $h^2(G, s_2)$ is smaller if c_2 is smaller. The right-hand side of (16) increases if c_2 decreases. Thus, subgame perfect equilibria in which only the less productive country provides the public good [as in E_1 in Fig. 2(a)] are less likely to exist if the productivity difference between the two countries is large.

We can consider the effects of marginal changes in c_1 and c_2 on the subgame perfect equilibrium further. We concentrate on the effects in an initial subgame perfect equilibrium in C in Figs. 3(a) and 3(b), in which MRS^1_{G,y_1} is higher than the slope of country 2's Engel curve in C. The effect of a small increase in c_1 is depicted in Fig. 3(a). Recall that in (C, C') only country 2 contributes to the public good, and country 1 is just indifferent as to whether to contribute a marginal unit or nothing at all. As CD only depends on the characteristics of country 2, the cost c_1 of country 1 does not affect this curve. However, due to the increase in c_1, country 1's income consumption curve pivots to the right [to $0C^*$ in Fig. 3(a)]. Let C^* denote the point where the old (and new) path MD and the new income consumption curve of country 1 intersect. Since we are considering a small change in c_1, C^* is the new equilibrium. The amount of public good provided decreases, and country 2 is worse off. Country 1 is better off since, where C

[8] Identical tastes are not sufficient to rule out a subgame perfect equilibrium with only the less productive country contributing. Suppose, for example, $m_1 = 100$, $m_2 = 0$, $s_1 = 1 = s_2 - \varepsilon$, and $u^i = y_i G$. Country 1 chooses the stage-2 equilibrium via $t_1 \in [0, M]$ that maximizes its utility. For $t_1 = 0$, the equilibrium is characterized by $y_1 = 50$, $g_1 = G^A = 50$, $g_2 = y_2 = 0$, and $u^1 = (50)^2$. The less productive country contributes to the public good. Closer inspection shows that $t_1 = 0$ is the subgame perfect equilibrium; it yields the highest utility for country 1 for any $t_1 \in [0, M]$. In particular, the equilibrium with perfect specialization according to C in Fig. 1 has $G^C = 100[(1+\varepsilon)/(3+\varepsilon)]$, and $u^1 = (33.\bar{3})^2 + \delta(\varepsilon)$ with $\lim_{\varepsilon \to 0} \delta(\varepsilon) = 0$. Therefore, country 1 chooses A instead of C and is the sole contributor to the public good, despite its productivity disadvantage.

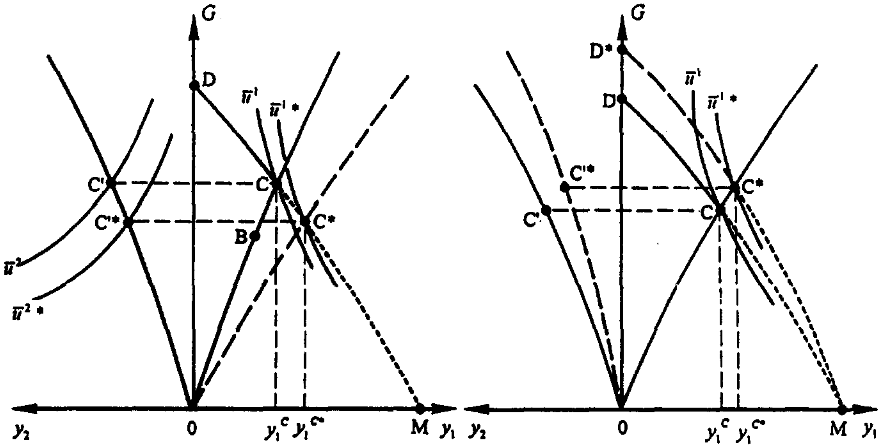

Fig. 3.

is the original equilibrium, country 1's indifference curve at C is steeper than the curve MD at C.[9]

For the intuition behind this puzzling result, consider equilibria in C and C^*. The allocation in C^* is technically feasible also with the original c_1. Country 1 could try to achieve C^* and the corresponding higher utility level by making transfers of $\mu_1 - y_1^{C^*}$ instead of $\mu_1 - y_1^C$. However, C^* would not be the Nash equilibrium in stage 2, since country 2 would expect country 1 to make positive contributions. Only if country 1 could commit to zero contributions in stage 2 C^* would be the equilibrium. When country 1's productivity s_1 goes down, $g_1 = 0$ indeed becomes country 1's best response and C^* becomes a Nash equilibrium in stage 2.

A decrease in c_2 can be treated similarly [see Fig. 3(b)]. It leaves country 1's income consumption curve unaffected. However, MD, the Engel curve of country 2, shifts outward toward MD^*, since, by the assumption of strict normality, country 2 provides more of the public good for any income level μ_2. Therefore, the amount of the public good increases. Also, the income consumption curve of country 2 pivots to the right. Country 1 is better-off, since C^* is to the upper right of C. Intuitively, even if country 1 were not to change its transfer to country 2, and, hence, would have the same amount of private good consumption $\mu_1 = y_1^C$, by its increased productivity country 2 would contribute more to the public good. But country 1 can do even better than that by a small cut in its transfer to country 2 by $y_1^{C^*} - y_1^C$. This also explains why country 2 can be better off or worse off; it is more efficient in

[9] Country 1's utility increases also for any large increase in c_1. The new equilibrium may then be an interior equilibrium like in Fig. 2(b), located somewhere between C and C^*.

contributing to the public good, but it receives a smaller income transfer in the new equilibrium.

5. Discussion

Section 4 showed that an upcoming game of private provision of a public good generates incentives for unconditional transfers: the country that receives these transfers does not promise to change its contributions or to take any action in exchange for the received transfer. However, the pure income effect induces it to increase its contribution to the public good. Whenever a situation without transfers leads to a private provision equilibrium in which both countries contribute, then in the subgame perfect equilibrium with transfers the country with the lower productivity makes a transfer that is so large that, in the stage-2 equilibrium, it becomes a non-contributor. That is to say, the subgame perfect equilibrium is characterized by full specialization according to the productivity advantage. For this specialization to occur the size of the productivity difference is inessential. An arbitrarily small difference is sufficient to generate full specialization.[10] There is some resemblance to standard basic trade theory. There, constant cost technologies also lead to specialization according to comparative advantages. The main difference there is that trade is a contract specifying who gives what. Here, the transfer leads to changed behavior by the recipient, but, unlike in trade theory, not because he is obliged to give something in return. The difference becomes more pronounced in the case where the public good is provided only by the country that has a comparative disadvantage in producing this good. This situation is more likely if country 1 is very rich and the more productive country's taste for the public good is comparatively weak. Specialization according to taste could not happen in standard trade theory.

We may compare the outcome here with the outcome of cooperative behavior. Given cooperative behavior, the solution on the aggregate amount of the public good fulfills the Samuelson–Lindahl condition. Instead, the subgame perfect non-cooperative equilibrium is typically characterized by underprovision of the public good: the country that specializes in contributions to the public good in the non-cooperative solution does not take into account the other country's benefit from additional units of the public good. Full specialization in terms of comparative advantages and side payments are often considered to be specific characteristics of collusive behavior. Here, monetary transfers and full specialization occur with non-cooperative

[10] This result has to be modified if the individual costs of contributing to the public good are increasing with the individual's contributions. However – without providing a proof here – it can be shown that an incentive for large voluntary transfers exists also in this case.

behavior in a situation without any binding commitment. Hence, it is not legitimate to make inferences from observing transfers and full specialization about the question of whether individuals play cooperatively or not.

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