The Distortive Effect of Efficient Negotiation Procedures[1]

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Abstract

In the last decade international and global environmental problems such as climate change have attracted much attention both in public debate and in economic research. As there is no world government, negotiations where terms of cooperative arrangements are laid down have to take place between the countries involved. In particular it must be determined, how much of the international public good is supplied and how the costs of providing the public good are shared between the countries. From the economic theory of federalism it is well known in principle that fiscal integration or international cooperation of different regions will influence the 'efforts' the different regions are willing to make. The cost-sharing rule for financing the provision of an international public good that the regions or countries have agreed on is not only decisive for the extent of the international measures, but it also influences decisions a country makes in the pre-agreement phases. Here, the participating countries are interested in promoting economic growth and improving the technologies for producing the public good, i.e. in the case of environmental problems in developing new abatement technologies. However, these pre-agreement measures determine the starting point for the negotiations and thus may have an impact on the subsequent cost sharing. In this paper we will show in the framework of a standard two period public-goods model that considerable incentives resulting from various forms of cost-sharing arrangements does indeed exist. Beyond Nash-bargaining and Lindahl cost sharing as the standard types of cost sharing, we will also analyze the effects of equal absolute and equal proportional cost sharing. This will enable us to compare the cost-sharing schemes according to the degree of inefficiency they imply.

JEL classification: H4, H7, Q2

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1 Motivation

In the last decade international and global public goods, such as climate protection or disease eradication, have attracted much attention both in public debate and in economic research (see Kaul et al. (2003) or Sandler (2004)). From the theory of public goods it is well-known that underprovision of a transnational public good is to be expected when the countries involved do not coordinate their actions. Therefore, cooperation between the countries is required to improve the allocation of public goods, but this can only rarely rely on pre-existing structures of international governance. In devising a cooperative scheme it must be determined, how much of the public good is provided and how its costs are shared among the nations.

Cooperative arrangements can be shaped in quite different ways as is well known from the economic theory of federalism. On the one hand, there may be full integration between the originally independent states by means of which a central government is established that has complete control over its regions. On the other hand, the countries, while preserving their sovereignty, enter into ad hoc negotiations whose aim is only to improve provision of a specific public good as with greenhouse-gas abatement in the Kyoto protocol. Between these two extremes there are cooperative regimes which rest upon fixed rules for determining the level of public-good supply and the pattern of cost sharing. A salient example for such a 'governance by rules' would be the application of the benefit principle that leads to burden sharing according to marginal willingness to pay (see Sandler (2004)). But there are also other cost-sharing rules, like equal absolute contributions to the public good, which might seem more relevant under empirical circumstances.

In a world with full and symmetric information, as is assumed here, all these different forms of cooperation will lead to an efficient solution given the same initial conditions. Then negotiations have at most different distributive effects. The fact that different cooperative mechanisms are equally efficient, however, no longer holds true if a prominent feature of the theory of federalism is taken into account: fiscal integration as implied by sharing the costs of an international public good will influence the 'efforts' the countries are willing to make at a first stage.[1] Before the decisions on public-good supply and burden sharing are reached at a second stage, the participating countries may use instruments such as taxes or subsidies to promote growth aimed at raising future national incomes. These measures at the pre-agreement stage determine the starting point for the subsequent cooperation

[1] In the case of a unilateral spillover between neighboring regions or countries, *Lülfesmann* (2002) analyzes the impact different governance structures have on decisions in the pre-agreement phase. In contrast, we focus on the differences in the incentive structure which are based instead on distinct negotiation procedures.

process and, in particular, for the ensuing distribution of costs.

When the countries make their decisions at the first stage they will anticipate the subsequent form of cooperation. However, as the cost-sharing rules applied at stage 2 may differ, this will affect the efforts of the countries at stage 1. As we show in this paper, the choice of a specific cooperation mechanism is not neutral for pre-agreement behavior and thus for the efficiency of the whole cooperative venture. As Brandt (2002, p. 709) puts it when dealing with the similar problem in a rather specific public-good framework with asymmetric information, 'expectations about design can have an effect on the actions of the countries before the negotiations take place.'[2]

Our paper, unlike the previous literature, considers mechanisms for efficient public-good provision[3] and show, in a first step, that considerable (dis)incentives at stage 1 are to be expected for a broad class of cost-sharing arrangements which generally can be attributed to the creation of positive externalities at stage 2. Then, in a second step, we will consider specific cost-sharing devices. Countries often negotiate these shares by forming rather loose and ad hoc agreements. A famous example for such a procedure is the Nash-bargaining solution where countries agree upon specific activities. Another ad hoc mechanism mimics competitive markets (Lindahl prices) such that the outcome seems to be close to a Walrasian equilibrium although the number of 'costumers' (countries) is rather small. In contrast to these complex mechanisms, in particular we analyze two rule-dependent mechanisms. According to Sandler (1997, p 143) 'complex interactions among states may best be fostered with the help of very simple structures': such a simple cost-sharing rule either sticks to equal absolute contributions (analogous to a lump-sum tax) or equal proportional sacrifices (analogous to a linear income tax) which have to be borne by the countries.

This enables us to compare the degree of inefficiency that is implied by the different cost-sharing schemes as a result of the disincentives that arise at stage 1. In particular, we show that only equal absolute cost sharing leads to an efficient degree of effort at the first stage of the game, whereas both Nash bargaining and cost sharing relative to the non-cooperative outcome imply considerable distortionary effects.

The paper is organized as follows. Section 2 presents the economic framework. As a point of reference, in section 3 the first-best allocation of the two-stage game is derived. A general description of the distortion which yields a disincentive to

[2]In a model where there is a contest at the pre-agreement stage the influence of bargaining design on preceding actions is also analyzed by *Anbarci et al.* (2002).

[3]Cf. *Buchholz and Konrad* (1995) and in the context of family economics *Konrad and Lommerud* (2000).

invest at the first stage of the game is given in section 4. Thereafter, a comparison is made of four prominent cost-sharing rules which provides some hints for their applicability in international negotiation processes. Section 6 extends the analysis to a broad class of mechanisms which explicitly focus on an improvement relative to a threat point like the non-cooperative status quo. A short conclusion summarizes our findings.

2 The Framework

Let two countries be given that are characterized by identical consumption preferences represented by a benefit function $b(x_i, G)$, where x_i is private consumption in country i and G is the provision level of a (pure) international public good and both goods are strictly normal. The benefits are increasing in both types of consumption and strictly concave. To avoid corner solutions, we assume that the indifference curves do not intersect the axes. Before countries enjoy consumption of private or public goods they have to produce or invest in some initial endowments. As countries are assumed to be perfectly symmetric, they have the same cost function $c(w_i)$ which describes the loss in benefit in country i when this country produces its initial endowment $w_i \in [0, \overline{w}]$. The cost function c is strictly monotone increasing in w_i, strictly convex and fulfils usual Inada conditions, i.e. $c' > 0$, $c'' > 0$, $\lim_{w_i \to 0} c'(w_i) = 0$ and $\lim_{w_i \to \overline{w}} c'(w_i) = \infty$. Aggregate payoff P_i in country i then combines benefits and costs

$$P_i = b(x_i, G) - c(w_i). \tag{1}$$

Initial endowments w_i in both countries can be used either for private consumption or for making a contribution to the public good. It is assumed that the marginal rate of transformation between the private and the public good is constant and equal to unity. Any feasible allocation (w_1, w_2, x_1, x_2, G) is then defined by the aggregate budget constraint

$$x_1 + x_2 + G = w_1 + w_2, \tag{2}$$

where each entry is non-negative, i.e. $w_i \geq 0$, $x_i \geq 0$ and $G \geq 0$.

We assume that the choice of the initial endowments (w_1, w_2) is made at stage 1 of a two-stage game. Subsequently, at stage 2 countries provide the public good, given (w_1, w_2) chosen at stage 1. In the different scenarios (Nash-bargaining, Lindahl and other cost sharing mechanisms) considered here, there is always a fully cooperative solution at stage 2 which leads to an ex post efficient provision of the public good, i.e. an outcome which is Pareto efficient conditional on the previously determined income levels w_1 and w_2.

We now want to analyze which levels of initial endowments the countries will choose at stage 1, when they completely anticipate the stage 2 outcome that results under different cooperative regimes. In order to describe the subgame-perfect equilibrium of this two-stage game, we will make use of the first-best allocation which is described in the following section.

3 Full Integration: The First-Best Solution

In this scenario, which we introduce as a benchmark case, the two countries merge such that after unification a common decision that maximizes aggregate welfare of both countries is made.[4] As countries are identical, we focus on the symmetric first-best allocation in which countries have the same initial endowment w. This solution is characterized by

$$\max_{w,G} b(w - 0.5G, G) - c(w). \tag{3}$$

Corresponding to the two stages of the decision process, we can separate this optimization into two steps. First, given the same initial endowment w in both countries, a provision level $G^S(w)$ is determined which maximizes the benefit in (3), i.e.

$$G^S(w) := \arg\max_G b(w - 0.5G, G). \tag{4}$$

If we now define the function $V(w) := b(w - 0.5G^S(w), G^S(w))$ for any given initial endowment w, then – as a second step – the choice the optimal endowment w^* is given by

$$\max_w V(w) - c(w). \tag{5}$$

By applying the envelope theorem to the derivative of $V(w)$, the first–order condition becomes

$$V'(w) = b_1(w - 0.5G^S(w), G^S(w)) = c'(w). \tag{6}$$

Given our assumptions, $V(w)$ is increasing and strictly concave function (see appendix A). In the first-best situation the marginal benefit of an additional dollar and the marginal costs of producing that initial endowment must be identical. By strict concavity of $V(w)$ and strict convexity of $c(w)$ the first-best level w^* is uniquely

[4] In terms of fiscal federalism a 'virtual' merger of the two regions aims at centralized governance. In what follows, we are interested in whether, and under which condition, a decentralized federal system of negotiating states works equally well as a federal government. In that case, from the perspective of Oates' (1972) famous 'decentralization theorem' a central government would not be required. If we think of the EU as an emerging federal system, this can be understood as an argument for taming Brussels and strengthening subsidiarity.

defined. Then $(w^*, G^S(w^*))$ is a symmetric Pareto optimal solution which would be achieved after full integration of the countries. In contrast to that benchmark, in the following we will consider situations of partial integration. This means that there are no contracts available concerning actions at stage 1 where the endowments are chosen. This is a common feature of international cooperation and fits best with the nature of negotiations and the reality of international agreements. The different countries want to preserve autonomy as far as possible so that cooperation is restricted to a well defined purpose, which, in the context considered here, is to improve the provision of an international public good.

4 Cooperation Distorts the Investment Decision

At stage 2, subsequent to the non-cooperative choice of the initial endowments at stage 1, both countries implement and finance an efficient provision of the public good by applying a cooperative mechanism M. For any given pair of initial endowments (w_1, w_2) the cooperative mechanism M then determines which allocation $(x_1^M(w_1, w_2), x_2^M(w_1, w_2), G^M(w_1, w_2))$ is chosen among all feasible allocations. Some relevant incentive effects on the choice of the income at stage 1 hold for a broad class of mechanisms that can be observed:

- The resulting allocation $(x_1^M(w_1, w_2), x_2^M(w_1, w_2), G^M(w_1, w_2))$ is **ex post efficient and smooth**, i.e. for any given initial endowments (w_1, w_2) the provision of the public good exhibits a Pareto optimum and the functions that describe the allocation are at least twice continuously differentiable.

- **Anonymity** holds, i.e. if the initial endowments are identical in both countries, the mechanism generates a symmetric outcome. This, in turn, yields $G^M(w, w) = G^S(w)$ according to (4) and then $x_1^M(w, w) = x_2^M(w, w) = w - 0.5G^S(w)$. In other words, 'equals should be treated equally' which corresponds to the principle of horizontal equity.

Now we ask which endowment levels the countries will choose at stage 1 when they act non-cooperatively at that stage and anticipate that, given any pair of initial endowments, the final outcome is determined according to the resource-allocation mechanism M at stage 2 of the game.

In order to find out subgame-perfect equilibria of the entire two-stage game we have to consider at stage 1 the best responses for any given w_j of the other country

$$w_i^r(w_j) = \arg\max_{w_i} \left[b(x_i^M(w_i, w_j), G^M(w_i, w_j)) - c(w_i) \right]. \tag{7}$$

The best responses are characterized by a first-order condition which equates marginal benefits and marginal costs

$$b_1 \frac{\partial x_i^M}{\partial w_i} + b_2 \frac{\partial G^M}{\partial w_i} = c'(w_i). \tag{8}$$

As we have assumed identical countries we will concentrate on symmetric subgame-perfect equilibria. Under regular conditions existence of an interior equilibrium with an income level $w^M > 0$ is guaranteed (see appendix B).

For a closer characterization of w^M it is important to infer how the benefit of one country, say country i, changes if it - starting from a symmetric allocation with $w_i = w_j = w$ - unilaterally increases its initial endowment. As the assumption of ex post efficiency implies that $G^M(w) = G^S(w)$ and $b_2/b_1 = 0.5$ follows from symmetry, this change of benefit is described by

$$\left[b_1 \frac{\partial x_i^M}{\partial w_i} + b_2 \frac{\partial G^M}{\partial w_i}\right]_{w_i=w_j=w} = b_1 \left[\frac{\partial x_i^M}{\partial w_i} + 0.5 \frac{\partial G^M}{\partial w_i}\right]_{w_i=w_j=w} = V'(w)\alpha^M(w), \tag{9}$$

where the function $\alpha^M(w)$ is a shorthand for

$$\alpha^M(w) = \left[\frac{\partial x_i^M}{\partial w_i} + 0.5 \frac{\partial G^M}{\partial w_i}\right]_{w_i=w_j=w} \tag{10}$$

For $\alpha^M(w) > 0$ country i should not lose under the mechanism M when it unilaterally increases its initial endowment starting from $w_1 = w_2 = w$. This seems to be a minimum fairness requirement for M.

We can now give a marginal condition for the initial endowment w^M that is chosen in a symmetric subgame-perfect equilibrium under a mechanism M. The initial endowment w^M chosen by both countries at stage 1 of a symmetric subgame-perfect equilibrium is characterized by

$$\alpha^M V'(w^M) = c'(w^M). \tag{11}$$

To abbreviate notation we set $\alpha^M := \alpha^M(w^M)$ for the equilibrium value of α under a given mechanism M. The way in which the choice of the initial endowment at stage 1 is distorted by the allocation mechanism M depends on the size of the factor α^M as $V(w)$ is concave and $c(w)$ is strictly convex.

Relative to the first-best endowment level w^* given by (6), both countries in the subgame-perfect equilibrium will choose an inefficiently low endowment level $w^M < w^*$ if $\alpha^M < 1$. If, however, $\alpha^M > 1$ the endowment level would be too high. Only for $\alpha^M = 1$ does the allocation mechanism not exhibit a distortive effect and both countries voluntarily choose the first-best endowment level.

These possibilities, however, are not equally relevant. Instead $\alpha^M \leq 1$ will be the standard situation, so that a too high endowment level cannot occur. To show this, we establish how country j's payoff P_j would change if country i increases w_i starting from a symmetric initial endowment w^M. Differentiating P_j at (x_1^M, x_2^M, G^M) with respect to w_i and rearranging terms gives

$$\frac{\partial P_j}{\partial w_i} = b_1 \frac{\partial x_j^M}{\partial w_i} + b_2 \frac{\partial G^M}{\partial w_i} = V'(w^M)\left[1 - \alpha^M\right]. \tag{12}$$

If country j does not have a disadvantage when country i unilaterally increases its initial endowment, i.e. $\partial P_j/\partial w_i \geq 0$, so that by (12) we have $\alpha^M \leq 1$. If country j is strictly made better off by the increase of w_i our relation becomes strong, i.e. $\alpha^M < 1$. These assumptions concerning the spillovers may be coined as **weak and strong monotonicity**, respectively. As the costs of providing additional income are private, it is intuitively clear that such spillovers lead to an undersupply of endowment at stage 1. Comparing (11) and (12) shows the ratio of the benefit gains $\alpha^M/(1-\alpha^M)$ between country i and j which is decisive for the degree of the distortion. The smaller this ratio, the smaller is w^M and, in turn, the higher the welfare loss implied by M. This directly follows from the concavity of V and the convexity of c.

We summarize those findings as follows: weak (strong) monotonicity of the mechanism M implies $w^M \leq w^*$ ($w^M < w^*$). A stronger benefit spillover to the other country – when one country changes its initial endowment – intensifies the distortionary effect caused by M.

After these general considerations we are now going to rank specific cooperative mechanisms according to the implied degree of inefficiency measured by α^M.

5 How Distortive are the Mechanisms?

Although almost all mechanisms that fulfill our axioms are inefficient at the first stage, they need not be identically distortive. In what follows, we will analyze the most important mechanisms like Nash bargaining, Lindahl prices, and fair cost-sharing concepts like an equal absolute or equal relative sacrifice. As we are interested in comparing the relative extent of the distortion we need more precise information on the size of the parameter α^M for different allocation mechanisms. It turns out that the size of α^M crucially depends on the type of the allocation mechanism being applied.

5.1 Nash Bargaining: Mechanism B

In order to determine the threat point of the Nash bargaining process we first have to look at the non-cooperative Cournot-Nash equilibrium that results for given initial endowments (w_1, w_2). As we focus on symmetric subgame-perfect equilibria at stage 1, we can without loss of generality restrict the analysis to those combinations (w_1, w_2) which yield an **interior** Cournot-Nash equilibrium, i.e. each country makes a strictly positive contribution to the public good. It is a consequence of the well-known Warr neutrality that such an interior Cournot-Nash equilibrium depends only on the **aggregate** initial endowment $w_1 + w_2$. Furthermore, as the two countries have identical preferences, private consumption is identical in an interior Cournot-Nash equilibrium.[5] Thus, in the Cournot-Nash equilibrium N private and public consumption as well as the benefit in each country are given by

$$\begin{aligned} G^N(w_1, w_2) &= G^N(w_1 + w_2) \\ x^N(w_1, w_2) &= 0.5 \left[w_1 + w_2 - G^N(w_1 + w_2) \right], \text{ and} \\ b^N(w_1, w_2) &= b\left(x^N(w_1, w_2), G^N(w_1 + w_2) \right). \end{aligned} \tag{13}$$

In the case of identical preferences, interior Cournot-Nash equilibria will be sustained by endowment levels that are equal or rather similar, which corresponds to the symmetric situation considered here. Then for any combination $(w_1 + w_2)$ that yields an interior Cournot-Nash equilibrium

$$(T_1(w_1, w_2), T_2(w_1, w_2)) = \left(b^N(w_1, w_2) - c(w_1), b^N(w_1, w_2) - c(w_2) \right) \tag{14}$$

constitutes the threat point of the Nash-bargaining process B, that serves as a specific allocation mechanism at stage 2. Assuming equal bargaining power in both countries the Nash-bargaining solution $\left(x_1^B(w_1, w_2), x_2^B(w_1, w_2), G^B(w_1, w_2) \right)$ is found by maximizing the Nash product with equal weight for both countries

$$\begin{aligned} & [b(x_1, G) - c(w_1) - T_1(w_1, w_2)] \, [b(x_2, G) - c(w_2) - T_2(w_1, w_2)] \\ = \; & \left[b(x_1, G) - b^N(w_1, w_2) \right] \left[b(x_2, G) - b^N(w_1, w_2) \right] \end{aligned} \tag{15}$$

among all feasible allocations that fulfill the aggregate budget constraint (2) given (w_1, w_2). As the cost levels $c(w_i)$ cancel out in the Nash product, the effective threat point $\left(b^N(w_1, w_2), b^N(w_1, w_2) \right)$ is symmetric according to Warr neutrality. For any given aggregate endowment $(w_1 + w_2)$ the outcome of Nash bargaining is a symmetric

[5] For details see *Warr* (1983) or *Cornes and Sandler* (1996).

Pareto optimal solution which is independent of the value of the threat point itself.[6] It turns out that the negotiations end up with an allocation that solves problem (4) when the identical initial endowment w corresponds to the average national endowment $0.5(w_1 + w_2)$. Hence, we obtain

$$\begin{aligned} G^B(w_1, w_2) &= G^S\left(\frac{w_1+w_2}{2}\right), \text{ and} \\ x_i^B(w_1, w_2) &= x^S\left(\frac{w_1+w_2}{2}\right) = 0.5\left[w_1 + w_2 - G^S\left(\frac{w_1+w_2}{2}\right)\right]. \end{aligned} \tag{16}$$

These equations clearly show that Nash bargaining implies some implicit pooling of the endowment between the two countries. This fiscal externality through pooling of resources accounts for the distortion in the endowment choice at stage 1. In what follows, we describe the distortion in more detail.

Let w^B denote the level of initial endowment chosen by both countries in the subgame-perfect equilibrium at stage 1 anticipating that at stage 2 a Nash-bargaining mechanism will be applied. Using the 'demand' properties in (16) it is easy to calculate α^B that indicates the degree of distortion at stage 1:

$$\alpha^B = \frac{\partial x_i^B}{\partial w_i} + 0.5\frac{\partial G^B}{\partial w_i} = 0.5\left[1 - 0.5\frac{\partial G^S}{\partial w_i}\right] + 0.5 * 0.5\frac{\partial G^S}{\partial w_i} = 0.5. \tag{17}$$

The latter equation immediately shows that investment in initial endowments will be too low compared to the optimal level, i.e. $w^B < w^*$.

The Nash-bargaining procedure in our case can be understood as perfect or fair pooling. The two parties split the aggregate gain in benefits 50:50. Or, the other way round, a country's investment in its initial endowment creates private cost only, while the gains from this investment are perfectly public, i.e. symmetrically spread over the countries.

5.2 Cost Sharing According to Marginal Willingness to Pay: Mechanism L

There is a long tradition in economics to see cost sharing according to marginal willingness to pay (MWTP) as an ideal outcome of a cooperative venture. At least as a benchmark, the MWTP-principle is also applied to transnational public goods in particular as it seems rather promising from the efficiency point of view (see

[6] In all nearly symmetric cases, it turns out that the result of this procedure does not depend on whether a threat point will be considered (i.e. there is a risk that negotiations fail for exogenous reasons) or the outside-option principle will be applied (i.e. negotiations never end in disagreement), cf. Muthoo (1999).

Sandler 2004, pp. for a discussion on that). In a public-good economy in which the marginal rate of transformation between the private and the public good is equal across countries, the MWTP-principle as a cost-sharing rule leads to the famous Lindahl equilibrium. The solution can thus be seen as the possible outcome of successful negotiations. According to Bergstrom (2004, ch. 4) Lindahl prices have very attractive properties as they propose some kind of equitable cost sharing which, in turn, promotes harmony in negotiation processes.

Given any combination (w_1, w_2) of initial endowments chosen at stage 1, the corresponding Lindahl equilibrium is implemented at stage 2. Depending on the previous choice of the initial endowments, the Lindahl mechanism implements another Pareto-optimal allocation. Let $G^L(w_1, w_2)$ denote the provision level of the public good in the Lindahl case. In equilibrium, each country i has to pay its individual Lindahl price $p_i^L(w_1, w_2)$ when financing the public good $G^L(w_1, w_2)$. As in our case Lindahl prices cannot exceed unity, they may also be interpreted as cost shares which lie between zero and 100%. In country i the Lindahl mechanism yields private consumption

$$\begin{aligned} x_i^L(w_1, w_2) &= w_i - p_i^L(w_1, w_2)G^L(w_1, w_2), \text{ where} \\ G^L(w_1, w_2) &= \arg\max_G b\left(w_i - p_i^L(w_1, w_2)G, G\right). \end{aligned} \tag{18}$$

Let w^L be the initial endowment chosen in any country in this specific subgame-perfect equilibrium when the application of the Lindahl mechanism at stage 2 is anticipated. In the same manner as with Nash bargaining considered previously, we can now calculate the distribution parameter α^L in the Lindahl case. Using (18) and the fact that symmetry implies $p_i^L = 0.5$, we obtain

$$\alpha^L = \frac{\partial x_i^L}{\partial w_i} + 0.5\frac{\partial G^L}{\partial w_i} = 1 - \frac{\partial p_i^L}{\partial w_i}G^L. \tag{19}$$

It is a well-known fact that $\partial p_i^L / \partial w_i > 0$ holds, i.e. the Lindahl price of country i is positively correlated with its initial endowment w_i (see Appendix C). Therefore, $\alpha^L < 1$ and consequently $w^L < w^*$. This says that an application of the Lindahl mechanism at stage 2 will cause an underprovision of the initial endowment at stage 1.

5.3 Absolute Sacrifice: Mechanism A

Let A be the allocation mechanism that, for any given initial endowment (w_1, w_2), picks out an allocation $\left(x_1^A(w_1, w_2), x_2^A(w_1, w_2), G^A(w_1, w_2)\right)$ in which both countries make identical contributions to the public good. This means that, in providing the public good, there is always an equal absolute sacrifice with respect to consumption (like a head tax) which can be interpreted as an obvious fairness requirement. Then for any (w_1, w_2)

$$\begin{aligned} w_1 - x_1^A(w_1, w_2) &= w_2 - x_2^A(w_1, w_2) = 0.5G^A(w_1, w_2) \text{ holds, such that} \\ \alpha^A &= \frac{\partial x_i^A}{\partial w_i} + 0.5\frac{\partial G^A}{\partial w_i} = \frac{\partial (w_i - 0.5G^A)}{\partial w_i} + 0.5\frac{\partial G^A}{\partial w_i} = 1. \end{aligned} \tag{20}$$

Therefore, this simple allocation mechanism does not cause any distortion, but will instead implement the first-best outcome as a subgame-perfect equilibrium.

5.4 Relative Sacrifice: Mechanism R

Let us now look at another mechanism which has certain fairness attributes. Instead of an identical absolute sacrifice we assume that equal relative sacrifice in the private consumption is adopted as fairness principle and serves as the basis of an allocation mechanism R which – for any given initial endowments (w_1, w_2) – determines an allocation $\left(x_1^R(w_1, w_2), x_2^R(w_1, w_2), G^R(w_1, w_2)\right)$. Then

$$\frac{w_i - x_i^R(w_1, w_2)}{w_i} = \frac{w_j - x_j^R(w_1, w_2)}{w_j} =: \tau^R \tag{21}$$

holds for any (w_1, w_2), where τ^R is a measure for the equal relative sacrifice needed for financing the public good and can be interpreted as a proportional income tax. Then by a short calculation

$$G^R(w_1, w_2) = w_1 + w_2 - x_i^R(w_1, w_2)\left[1 + \frac{w_j}{w_i}\right], \tag{22}$$

which, in turn, gives

$$\alpha^R = \frac{\partial x_i^R}{\partial w_i} + 0.5\frac{\partial G^R}{\partial w_i} = 0.5\left[1 + \frac{x_i^R}{w_R}\right] = 1 - 0.5\tau^R. \tag{23}$$

Therefore, as $1 > \tau^R > 0$, we obtain $\alpha^R \in (0.5; 1)$. Thus, proportional cost sharing is distortive as redistribution through an income tax gives rise to disincentives at stage 1 of the entire game.[7]

[7] In a somehow related context of international pollution control, Eyckmans (1997) pointed out that proportional cost sharing may yield an outcome where not all countries are better off under cooperation.

5.5 A Comparison of A, B, L and R

How these different mechanisms work, when a certain combination of initial endowments is given, can be shown in figure 1 below, see *Cornes and Sandler* (1996, ch. 6-7) for a similar graphical representation. For a given combination of initial resources (w_1, w_2), all feasible consumption bundles (x_1, x_2) lie below the broken budget line. Consequently, the greater the distance from this line, the higher the public-good supply. All ex post efficient allocations are depicted on the PP-line and give the set of possible outcomes of a negotiation. They only differ with respect to the distribution of the benefits. According to our previous analysis, the equilibrium points depend on the mechanisms applied. For mechanism A the identical absolute sacrifice of both countries leads to a point which lies on a parallel to the 45°-line starting from the point characterized by the initial endowment. The mechanism R, however, is shown by the intersection of the ray from the origin to (w_1, w_2) and the PP-line. Warr neutrality causes symmetry of the Nash-bargaining solution which, in turn, yields a point on the 45°-line.

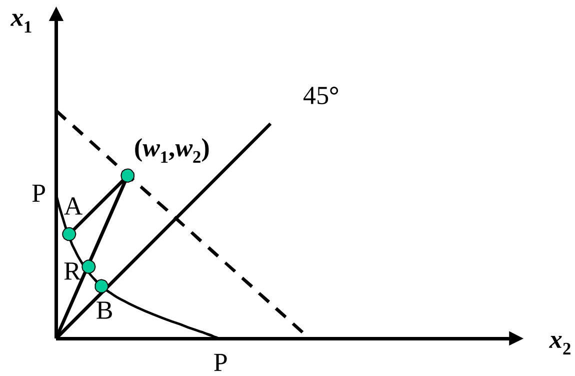

Figure 1: Different Allocation Mechanisms

Using the results of the previous sections, we now want to compare the distortionary effects on the choice of initial endowments that are implied by these mechanism. While it turns out that for mechanisms A and B the parameters α^A and α^B, which indicate the size of the distortion, are independent of countries' preferences, with mechanism R the distortive effect depends on the demand for the public good. However, it is evident from the considerations above that the distortion caused by R is weaker than with Nash bargaining B and stronger than with cost sharing according to equal absolute sacrifice A. Furthermore, it becomes less distortive, the lower the relative sacrifice τ^R.

As the Lindahl mechanism does not fix the cost share of each country ex ante, it is a priori not clear how the distortionary effect of this mechanism is related to that of A and B. However, we know that a unilateral increase of the initial endowment by one country will increase the other country's benefit in the Lindahl equilibrium. In figure 1 this means that point L must lie somewhere below A. Following the previous results, this general observation on the comparative statics of Lindahl equilibria implies that $\alpha^L < \alpha^A = 1$. The Lindahl mechanism is distortionary while the equal absolute sacrifice is not.

As a next step we now want to compare the mechanism L with Nash bargaining B. It can be shown that $0.5 < \alpha^L$ which, according to (19), is equivalent to

$$0.5 > \frac{\partial p_i^L(w^L, w^L)}{\partial w_i} G^L(w^L, w^L). \tag{24}$$

General properties of Lindahl equilibria imply that the above inequality is always valid (see Appendix C). Thus the Lindahl mechanism is less distortive than Nash bargaining, i.e. $0.5 = \alpha^B < \alpha^L$. This means that in the Lindahl regime the decision to produce initial endowments is less distorted than in the Nash-bargaining regime. The reason is that in the Nash-bargaining solution income of the negotiating countries is perfectly pooled, whereas in the Lindahl outcome everyone's cost share for the provision of the public good depends on the individual ability to pay, i.e. according to the initial endowment. This shows that the way in which cooperation decisions are made may considerably affect the outcome.

Our results can be summarized as follows.[8] Different types of cooperation rules induce different incentives for choosing the initial endowments at the previous stage. They distort the allocation and rank according to their degree of inefficiency

$$w^* = w^A > (w^L, w^R) > w^B, \tag{25}$$

which – given the normality of demand $G^S(w)$ – yields an underprovision of the public good

$$G^* = G^A > (G^L, G^R) > G^B. \tag{26}$$

However, in general there is no identity and no a priori ranking of the mechanisms

[8] In their contest-theoretic model *Anbarci et al.* (2002) give an analogous welfare ranking for bargaining solutions like 'split-the-surplus', 'Kalai-Smorodinsky' or 'equal sacrifice'. In contrast to our cost-sharing approach, the bargaining mechanisms they considered focus on a somehow fair division of welfare differences while we concentrate on a fair choice of instrument variables. Additionally, in our approach we are able to analyze the implications of the most prominent mechanisms, Nash bargaining and Lindahlian cost shares.

L and R according to their inefficiency.[9]

For all the specific cooperation mechanisms A, B, L and R considered up to now, the parameter α which indicates the size of the distortionary effect is bounded from below by 0.5. That the distortion is thus of limited extent can be explained by a fairness property that all these mechanisms have in common: when, starting from a symmetric position, country i increases its initial endowment its consumption benefits are not lower that those of its free-riding counterpart j. Thus, no 'advantage of being poor'[10] exists and this avoids a 'ruinous competition' between the countries. Preventing too much distortion in this way is good news for the mechanisms. But are all cooperative rules characterized by this positive feature? The answer is 'no' which will be a main result in the next section.

6 Cost Sharing Relative to Non-Cooperation

Until now we have analyzed mechanisms which, except for Nash bargaining, lead to a cost-sharing rule independent of the non-cooperative fallback position. However, as a consequence of Warr neutrality, the status quo has had no impact at all, even in case of Nash bargaining. In what follows, we introduce additional mechanisms where the threat point plays a decisive role. This is in line with current international negotiation processes that focus on appropriate measures for overcoming the underprovision problem relative to the non-cooperative status quo. When countries bargain, they often think in terms of splitting the additional costs of cooperation among the parties. Hence, in that case, the cost-sharing rules only refer to the costs of providing the amount of the public good that exceeds that in the Cournot-Nash equilibrium.

The mechanisms A, L and R, as considered before can be adapted in a straightforward way to provide such rules for cost sharing relative to the non-cooperative outcome. If we apply the new mechanisms called $A^{'}$, $L^{'}$ and $R^{'}$, the disincentives to invest in initial endowments may change. How this happens exactly will now be analyzed. First, we show that the adapted Lindahl mechanism $L^{'}$ and the equal absolute sacrifice rule $A^{'}$ lead to the same distortion as Nash bargaining $B = B'$, i.e. $\alpha^{L^{'}} = \alpha^{A^{'}} = \alpha^{B^{'}} = 0.5$ holds. This surprising equivalence result is a straightforward implication of Warr neutrality where the non-cooperative Nash equilibrium, which gives the threat point of the bargaining process, yields an allocation of private and public consumption that is independent of the income distribution. The argument

[9] Note that in the case of an identical symmetric log-linear benefit function $b(x_i, G) = \ln x_i + \ln G$ in both countries, the allocation mechanisms L and R coincide.

[10] See *Konrad* (1994) for this phrasing.

runs as follows.

Consider a combination of initial endowments (w_1, w_2) that leads to an interior Cournot-Nash equilibrium in which public-good provision is $G^N(w_1 + w_2)$ and private consumption is – according to Warr neutrality – identical in the two countries $x^N(w_1 + w_2)$. For an application of either A', L' or R' the status quo consumption expenditures $x^N(w_1 + w_2)$ build the disposable income of each country which can be spent for either expanding provision of the public good or private consumption.

Then postulating that in the attained efficient solution both countries make the same additional contribution out of $x^N(w_1 + w_2)$ implies that A' implements the symmetric Pareto optimum. Therefore, $\alpha^{A'} = 0.5$ characterizes a uniform split of the gains from the investment decision. It follows from the analysis in subsection 5.1 that the distortionary effect must be identical with that in Nash bargaining.

The same line of argument runs through for the modified Lindahl mechanism L'. Here, the two countries share the costs the provision of the public good that exceeds the Cournot-Nash provision level $G^N(w_1 + w_2)$. Having identical preferences and starting from the same disposable income $x^N(w_1 + w_2)$, the equilibrium cost shares are uniform, i.e. $p_1^{L'} = p_2^{L'} = 0.5$. Given (w_1, w_2), the mechanism L' – just as B and A' before – leads to the symmetric Pareto optimum. Therefore, L' is identical with B and A' and $\alpha^{L'} = 0.5$ holds.

The result that $\alpha^{L'} = \alpha^{A'} = \alpha^B = 0.5$ has its origin in the symmetry of the status quo implied by Warr neutrality and the symmetrical treatment of both countries. Irrespective of which mechanism A', B or L' is applied, an investment in marginal endowment made by one country leads to the same change in the private consumption for both countries in the final allocation so that the increase in consumption benefit is evenly spread. According to the reasoning leading to previous results, all these mechanisms must therefore have the same distortionary effect.

When, however, the mechanism R' is applied matters become quite different. The condition that describes R' is

$$\frac{x_i^N(w_i + w_j) - x_i^{R'}(w_i, w_j)}{w_i} = \frac{x_j^N(w_i + w_j) - x_j^{R'}(w_i, w_j)}{w_j}. \tag{27}$$

Given (w_1, w_2) in figure 1, the mechanism R' picks out the allocation that lies at the point of intersection between the Pareto efficiency line PP and the straight line through the Cournot-Nash equilibrium (on the 45°-line) which has the slope w_2/w_1.

By taking the partial derivative with respect to w_i in (27), it follows for the symmetric case with $w_i = w_j = w$

$$\frac{\partial x_i^{R'}}{\partial w_i} = \frac{\partial x_j^{R'}}{\partial w_i} + \frac{1}{w}\left[x_j^{R'}(w, w) - x^N(2w)\right]. \tag{28}$$

As the non-cooperative status quo consumption exceeds that under cooperation, the equation above implies the following relation

$$\frac{\partial x_i^{R'}}{\partial w_i} < \frac{\partial x_j^{R'}}{\partial w_i}. \tag{29}$$

Thus the country with higher income ultimately has less private consumption and thus a lower consumption benefit. This advantage of being poor yields $\alpha^{R'} < 0.5$. The mechanism R' that might seem particularly fair at first sight thus has the worst allocative consequences among all mechanisms considered here.

This follows because the wealthier country in total loses twice under R'. It does not only bear the investment cost for its higher initial endowment, but it also has to contribute more for financing the public-good supply than the poorer country. Consequently, the wealthier country is worse off in private consumption. Such a re-ranking provides a rather strong disincentive to invest in initial endowments. This ruinous competition between the countries makes clear why the mechanism R' is so disadvantageous.

But the other mechanisms too, that focus on cost sharing relative to the status quo show relatively poor results. Consequently, international cooperation should not rely on those mechanisms.

7 Conclusion

When a public good is to be provided and all agents have perfect information, the specification of cost-sharing rules could be expected to have no impact on efficiency. In a stylized world consisting of two countries with identical preferences and technologies this presumption means that, irrespective of the exact symmetric cooperation mechanism being applied, a Pareto optimal solution is always obtained in which both countries have the same levels of private consumption and benefit. While this assertion is true in case of exogenously given initial endowments, the final allocation becomes inefficient when the countries choose their endowments at a first stage. Then countries choose an inefficiently low income level in the subgame-perfect equilibrium. This is a well known result in the theory of public goods that highlights the strategic interactions between the countries. This paper has shown in a general setting how inefficiency in cooperation can be attributed to fiscal externalities that occur when one country increases its initial endowment. Additionally, it has been established that the size of this efficiency loss in cooperation crucially depends on the cooperation mechanism the countries are subject to: Nash bargaining scores worst, while equal absolute sacrifice can even sustain the first-best allocation. Cooperation schemes, like Lindahlian cost sharing or the equal relative sacrifice principle which take the relative income position of the countries into account, occupy positions in between. Even though all the mechanisms considered here show equal treatment of countries, there are considerable differences in the resulting cooperative solution.

From a more practical perspective, the results obtained in this paper can be interpreted in the following way. On the one hand, fixing ex ante simple burden-sharing rules may improve allocative efficiency considerably as compared to negotiations ad hoc. A further argument is thus provided that supports the alleged inefficiency of bargaining. On the other hand, the cost-sharing mechanism which postulates equal absolute contributions to the public good for all countries is usually considered unfair because it does not pay regard to differences in ability to pay caused by unequal endowments. This indicates that even among the different rules of cooperative arrangements there is some equity-efficiency trade-off.

Appendix A: Concavity of the Value Function

The strict concavity of b implies that the value function $V(w)$ is also strictly concave. Concavity can be shown by totally differentiating the LHS of (6). We obtain

$$V'' = b_{11} + [b_{12} - 0.5b_{11}] \frac{\partial G^S}{\partial w} = \frac{b_{11}b_{22} - (b_{12})^2}{b_{11}(b_2/b_1)^2 + b_{22} - b_{12}} < 0,$$

where the second equation uses the comparative statics of (4). Obviously, the sign of V'' is negative since the benefit function was assumed to be strictly concave, i.e. the numerator is positive, and as strict concavity of a function implies its strict quasi-concavity the denominator becomes negative too (cf. *Sydsæter, Strøm and Berck* (1999), p. 83 - 86).

Appendix B: Existence of Subgame-perfect Equilibria

The existence of such a symmetric solution is ensured by the following three arguments. First, since country i's payoff will normally be concave in its own initial endowment (see below) and continuous in j's strategy, the best response is single valued such that there exists a continuous best-response function $w_i^r(w_j)$ within the whole domain $[0, \overline{w}]$. Second, if $w_j = 0$, country i will choose a best response $w_i^r(0)$ which is bounded away from zero. Our assumptions with respect to the benefit function b imply that the LHS in (8) is strictly positive for $w_i = w_j = 0$ while $c'(0) = 0$. Thus, country i increases its initial endowment at least marginally above $w_i = 0$. Otherwise, country i would prefer to stay in a situation with no private and public consumption if the other country does not provide any initial endowment. Third, for $w_j = \overline{w}$, country i will choose $w_i^r(\overline{w}) < \overline{w}$ since $c'(\overline{w})$ is infinite while country i's marginal benefit from increasing w_i, i.e. LHS in (8), is finite at $w_i = w_j = \overline{w}$. Summarizing, as $w_i^r(0) > 0$ and $w_i^r(\overline{w}) < \overline{w}$, it follows from continuity that, given the mechanism M, there exists a solution to $w_i^r(w^M) = w^M$. Hence, w^M gives an interior symmetric equilibrium. However, we cannot exclude the existence of multiple equilibria.

Strict concavity: starting from country i's payoff (7) the second-order condition reads

$$\begin{pmatrix} x' & G' \end{pmatrix} \begin{pmatrix} b_{11} & b_{12} \\ b_{12} & b_{22} \end{pmatrix} \begin{pmatrix} x' \\ G' \end{pmatrix} + c'' + b_1 \widehat{\alpha}' < 0,$$

where x' is a shorthand for $\partial x_i^M / \partial w_i$ and G' for $\partial G^M / \partial w_i$. Furthermore, $\widehat{\alpha}' = x'' + \frac{b_2}{b_1} G''$ denotes the change in $\widehat{\alpha}$ which is defined analogous to α in (10) except for an arbitrary but constant $mrs = \frac{b_2}{b_1}$. The first term of the SOC is non-positive because strictly concave functions are negative semi-definite, the second term is strictly negative. The remaining third term is non-positive if the mechanisms applied are fair in a certain sense. A fair division of the gains from cooperation is given if the ratio of the benefit gains $\widehat{\alpha}/(1-\widehat{\alpha})$ is non-increasing when a country becomes richer, i.e. the relative bargaining power of a country must not be positively related to its initial endowment. Almost all cost-sharing mechanisms exhibit this property which, in turn, is sufficient to guarantee existence of subgame-perfect equilibria of the entire game.

Appendix C: Monotonicity of Lindahl Prices

Let $G_m(w,p)$ denote the Marshallian demand in each country that depends on this country's income w and its public-good price p. From normality, we have $\partial G_m/\partial w > 0$ and, by the Slutsky decomposition, we get $\partial G_m/\partial p = \partial G_h/\partial p - G \cdot \partial G_m/\partial w < 0$, where $\partial G_h/\partial p$ represents the substitution effect in terms of Hicksian demand.

Lindahl prices are defined through an identity of Marshallian demand for the public good in both countries. Thus, for the Lindahl prices $p_i^L(w_i,w_j)$ and $p_j^L(w_i,w_j)$ it holds that

$$G_m(w_i; p_i^L(w_i,w_j)) = G_m(w_j; p_j^L(w_i,w_j)) \tag{30}$$

for any pair (w_i,w_j) of initial endowments. Furthermore, as in equilibrium the Lindahl prices (cost shares) of the two countries add up to unity [i.e. $p_j^L(w_i,w_j) = 1 - p_i^L(w_i,w_j)$], an implicit differentiation of (30) yields

$$\frac{\partial p_i^L}{\partial w_i} = -\frac{\frac{\partial G_m}{\partial w_i}}{\frac{\partial G_m}{\partial p_i^L} + \frac{\partial G_m}{\partial p_j^L}} > 0, \tag{31}$$

where the partial derivatives are taken at the Lindahl equilibrium.

To show the validity of inequality (24) we have to consider $\partial p_i^L/\partial w_i$ for the case of symmetric endowments $(w_i = w_j = w^L)$ where $\partial G_m/\partial p_i^L = \partial G_m/\partial p_i^L$ holds. Using the Slutsky decomposition gives

$$\frac{\partial p_i^L}{\partial w_i}G = 0.5\frac{\frac{\partial G_m}{\partial w_i}G}{\frac{\partial G_m}{\partial w_i}G - \frac{\partial G_h}{\partial p_i^L}} < 0.5 \tag{32}$$

and thus (24).[11]

[11] For a comparative static analysis of Lindahl equilibria see *Sertel and Yildiz* (1998).

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