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Abstract. In an international setting, sovereignty of countries imposes serious problems on compliance and participation for a multilateral environmental agreement. This paper discusses both problems simultaneously in a three-country-setting. It employs a repeated-game-model and develops some basic conditions which agreements must meet. These conditions are applied on a specific model which allows only a subcoalition of two countries to join an agreement. However, this subcoalition is able to introduce transfer policies which initiate extra reductions of the outsider country. The paper shows that transfer policies may be based on a cost-inferior technology which makes non-compliance less attractive.

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1. Introduction

During the last decade, the public concern has shifted the focus of environmental problems from local hot spots to international or even global pollution problems, and so did environmental economics. Expanding the pollution-concerned area has created not only a new spatial problem. The challenge of international environmental policies is due to the lack of a central authority which is able enforce a specific environmental resource use. From an international perspective, regulation must be grounded on the voluntary participation of those countries which use and exploit the environmental resource. The sovereignty of countries implies that international environmental agreements must guarantee that every national participant is at least not worse off by fulfilling the requirements of the agreement voluntarily than by behaving opportunistically.

Because restricting international pollution provides a public good, environmentalists fear that the strategy of free riding will turn out as a dominant one of all countries and will deteriorate environmental quality significantly or even endanger human living conditions. Economists discussing international pollution problems are not in that way pessimistic although they do not always claim that full cooperation will emerge. Most of the respective literature concentrates on the possibility of stable coalitions as a subset of resource-using countries (see BARRETT, 1991, 1992, BAUER, 1992, CARRARO, SINISCALCO, 1993, HEAL, 1992). Stability demands that every sovereign member-country is always better off by remaining in the coalition than by leaving it and every outsider is always worse off by joining the coalition. Partial cooperation can emerge if the stable coalition contains more than one member.

However, these papers deal with the notion of sovereignty only in terms of voluntary participation. When countries have decided to sign an environmental treaty, they are supposed to behave compliant and to be able to stick credibly to the agreed-upon reduction policies. This paper addresses the problem that countries need not to behave compliant because they are always able to repudiate the demands of other countries as interfering with their sovereign affairs. It assumes that the agreed-upon reduction plans must be self-enforcing and that all countries decide simultaneously whether they fulfil the requirements of an agreed-upon policy or they breach the agreement. The questions of compliance and participation will be addressed to simultaneously.

Accordingly, the paper is organized as follows. Section 2 gives some basic conditions which multilateral environmental agreements must fulfil in a three-country-setting. Section 3 employs a specific model to shed some more light on this three-country-case. This model implies that only a subcoalition of two countries joins an environmental agreement. Section 4 demonstrates that the subcoalition's cooperation is not necessarily the end of international environmental policies when a subcoalition introduces transfer policies for extra reductions of the outsider country. Section 4 demonstrates also that the subcoalition may base transfer policies on a cost-inferior technology which makes non-compliance less attractive. Section 5 summarizes and concludes the paper.

2. Conditions for Multilateral Environmental Agreements

This section will outline five basic conditions which multilateral agreements must meet. All conditions are due to the sovereignty constraint which imposes restrictions on any agreement. The sovereignty constraint has a twofold implication. On the one hand, sovereignty implies that participation must be voluntary. In principle, no country can be forced to sign a multilateral agreement. On the other hand, sovereignty enables every country to breach the agreement whenever it likes to. Therefore, every multilateral environmental agreement must guarantee that every participating country is not better off by breaching the agreement than by fulfilling the requirements of the agreement.

This paper will deal with both features simultaneously. It assumes three countries i, j and k which suffer from mutual externalities caused by emissions. Restricting the externalities benefits every country, but every country is better off when only the other two countries introduce reduction measures. The benefits and the costs of reduction policies are common knowledge. As all countries decide simultaneously on their current reduction level, any multilateral environmental agreement can only be made self-enforcing by credible future actions which depend on past compliance. The notion of credibility acknowledges that an international environmental agreement is open for renegotiation. Thus, renegotiation-proofness determines conditions which multilateral environmental agreements must meet.

The model assumes that the utility of every country can be given by utility functions:

$$(1) \qquad \forall l \in \{i,j,k\}: \qquad U_l(R_i,R_j,R_k) = B_l(R) - C_l^0(R_l),$$

$$R = R_i + R_j + R_k,$$

$$\frac{dB_l}{dR} > 0, \frac{d^2B_l}{dR^2} \leq 0, \frac{dC_l}{dR_l} > 0, \frac{d^2C_l}{dR_l^2} > 0.$$

R_i, R_j and R_k denote the reductions of the respective countries, B_l and $C^0{}_l$ are the benefits and the costs which depend on the sum of reductions or the individual reductions, respectively.[1] Utility functions like (1) indicate that the problem in question is a global one (e.g. the climate problem) because reductions are a homogeneous service for all countries.

Obviously, all countries can be better off by a multilateral environmental agreement than by adjusting their reductions independently. The sovereignty constraint imposes certain restrictions on the agreement. This paper assumes that an international agreement should at least meet the conditions of weak renegotiation-proofness (Farrell, Maskin, 1989) and the conditions of coalition-proofness (Bernheim, Peleg, Whinston, 1987). Deriving solutions subject to the constraints weak renegotiation-proofness and coalition-proofness impose is motivated by empirical evidence. On the one hand, countries which have signed an agreement can always renegotiate after one country has breached the agreement. Therefore, punishment by non-cooperation in all future periods or by even worse equilibrium outcomes lacks credibility when renegotiation is possible. On the other hand, negotiations among all concerned countries do not guarantee that either an agreement is reached which covers all countries or no agreement is reached. Agreements of subcoalitions which meet the conditions of weak renegotiation-proofness for their parties cannot be ruled out but determine outside options.

The analytic framework of this paper is given by an infinitely repeated game. Because agreements specify reduction duties for all countries which have ratified the agreement, only pure strategies are considered. All countries discount future utilities by stationary discount factors δ_i, δ_j and δ_k, respectively. These discount factors mirror a crucial parameter of the model because they indicate the "impatience" of each country. An extremely impatient country can be imagined as a country facing significant domestic problems. These problems, e.g. problems of development and problems of unemployment, bias policy objectives towards aiming at short-run gains. If political issues are governed by the need for quick success, impatience reflects a higher degree of institutional instability if institutional stability is defined by the scope left to policy makers to deal with long-run problems at the expense of short-run gains.

The first three conditions which sovereignty imposes on multilateral environmental agreements are due to weak renegotiation-proofness. Weak renegotiation-proofness defines conditions for an agreement in the phase after one country has not fulfilled its reduction duties. Weak renegotiation-proofness reconciles the necessity of punishing a non-compliant country and the option of restarting cooperation. A weakly renegotiation-proof device is a

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1 The superscript 0 indicates the best available reduction technology. Section 4 will employ other technologies when transfer policies are discussed. As it is obvious that any joint reduction policy employs the least-cost technology, the technology choice will not yet be considered in this section in order to avoid unnecessary confusion.

rule laid down in the agreement that all countries except the non-compliant one will realize their "breach" levels after one country has not fulfilled its reduction duties. Restarting cooperation is possible because these countries will return to the agreed-upon reduction levels after the non-compliant country has met its agreed-upon obligations unilaterally in one period. This device is immune against renegotiations if the agreed-upon reductions induce a non-compliant country to carry its reduction level unilaterally in order to restart cooperation.

According to this punishment device, weak renegotiation-proofness defines three conditions.

Condition 1: *For every country, the long-run gains from cooperation must not fall short of the short-run gains of breaching the agreement in one period and no cooperation in all following periods.*

(C1) $\forall l \in \{i,j,k\}, \forall R_l^b$:

$$\frac{1}{1-\delta_l}U_l\left(R_l^*,R_{-l}^*\right) \geq U_l\left(R_l^b,R_{-l}^*\right) + \frac{\delta_l}{1-\delta_l}U_l\left(R_l',R_{-l}'\right)$$

R_l^* and R_{-l}^* denote the agreed-upon reduction level for country l and the vector of the agreed-upon reduction levels of the other countries, respectively. Note that R_l^* and R_{-l}^* do not necessarily give Pareto-optimal levels; if the conditions are too demanding, only lower levels can meet the conditions.[2] R_l^b and R_l' denote reduction levels which are associated with a breach and the non-cooperative reduction level of country l, respectively. This non-cooperative reduction level depends on the reduction levels of the other countries, R_{-l}'. Note also that Condition 1 assumes that every country has decided for joining a multilateral environmental agreement. It does not address the question whether participation benefits the country more than staying away from the agreement. Condition 5 will deal with this question.

(C1) is a basic condition for the agreement. This condition on its own defines the self-enforceability of an agreement if punishment by a grim strategy were credible and renegotiations were impossible. However, weak renegotiation-proofness adds another two conditions.

Condition 2: *Given that a non-compliant country wants to restart cooperation as soon as possible, the gains from cooperation must not fall short of breaching the agreement in one period and restarting cooperation by realizing its agreed-upon reduction level unilaterally.*

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2 A weakly renegotiation-proof agreement does always exist since at least the non-cooperative reduction levels fulfil the conditions.

(C2) $\forall l \in \{i,j,k\}, \forall R_l^b, \forall R_{-l}^b$:

$$[1+\delta_l]U_l(R_l^*,R_{-l}^*) \geq U_l(R_l^b,R_{-l}^*) + \delta_l U_l(R_l^*,R_{-l}^b)$$

Condition 3: ***After a country has breached the agreement, it wants to restart cooperation as soon as possible.***

(C3) $\forall l \in \{i,j,k\}, \forall R_{-l}^b$:

$$U_l(R_l^*,R_{-l}^b) + \frac{\delta_l}{1-\delta_l}U_l(R_l^*,R_{-l}^*) \geq \frac{1}{1-\delta_l}U_l(R_l',R_{-l}')$$

R_{-l}^b denotes the vector of reduction levels of the compliant countries after country l has breached the agreement. Condition 2 defines ex ante compliance in stating that every country must be weakly better off by fulfilling the agreement than by breaching it in one period and reinvesting in coöperation in the next period. Condition 2, however, assumes that a potentially non-compliant country wants to restart cooperation as soon as possible. The corresponding constraint is given in Condition 3 which defines ex post compliance.

Note that these conditions are stronger when compared to subgame-perfect stabilization mechanisms which include grim strategies, too. However, they are also weaker compared to the concept of strong renegotiation-proofness. Strong renegotiation-proofness acknowledges the possibility that every country which has breached the agreement can suggest a new agreement which should substitute for punishment and restarting cooperation according to the old agreement's device. If an alternative, also weakly renegotiation-proof agreement exists and Pareto-dominates punishment and restarting of cooperation, countries should be expected to renegotiate away from the old agreement, thereby making the old agreement's punishment incredible.

Neglecting this option for multilateral environmental agreements means assuming some kind of commitment of every country in that countries will never renegotiate for a new agreement after a breach. There is some empirical evidence which supports this commitment opportunity. Governments representing their countries in international negotiations can be assumed to refuse signing a new agreement because the public prefers cooperation and wants non-compliant countries to be punished. Additionally, any new agreement which Pareto-dominates punishment and restarting cooperation must compensate the compliant countries for their dispense with punishment by offering them more individual cooperation gains. This shift in individual cooperation gains may conflict with some generally accepted rules which determine how cooperation gains should be split among counties. Section 3 will develop explicit solutions for specific utility functions and for a certain split rule.

This paper discusses multilateral environmental agreements which potentially embrace three countries. This case is an important one because agreements which potentially embrace more than two countries need not only be immune against deviations of single countries but against deviations of subcoalitions as well. For the three-country-case, subcoalitions comprise two countries. Any of the three possible subcoalitions must not be better off by jointly exploiting the third country. The role of coalitions other than the grand coalition was formalized by the concept of coalition-proofness (Bernheim, Peleg, Whinston, 1987). Contrary to the Bernheim-Peleg-Whinston-paper, the assumption of an infinitely repeated game does not allow for taking the actions of a third party as given. Instead, if a third party is exploited by a subcoalition, this party will revert to its breach level until both parties have reinvested in a restarting cooperation by meeting their obligations. Additionally, the subcoalition's benefits from cheating for a coalition are determined not only by the benefits of breaching the agreement in one period, but also from the benefits of a subcoalition's cooperation in all following periods. If both non-compliant countries can do better than reverting to the non-cooperative reduction levels and if they do not want to restart cooperation, the formed subcoalition which exploited the third party will proceed with cooperation by a joint reduction policy. Condition 4 defines the corresponding constraints for a joint reduction policy in the grand coalition.

Condition 4: *Any subcoalition must not be better off by cheating in one period and a weakly renegotiation-proof agreement between the subcoalition's countries for the following periods, given the reductions of the third country.*

(C4) $\forall\{p,q\}\in\{\{i,j\},\{j,k\},\{i,k\}\},\forall l\in\{i,j,k\setminus p,q\},\forall R_p^b,\forall R_q^b,$

$$\forall\{\tilde{R}_p,\tilde{R}_q,R_l'\}\in\{R_p^*,R_q^*|R_l=R_l'\}:$$

$$U_p(R_p^b,R_q^b,R_l^*)+\frac{\delta_p}{1-\delta_p}U_p(\tilde{R}_p,\tilde{R}_q,R_l')\le\frac{1}{1-\delta_p}U_p(R_p^*,R_q^*,R_l^*)$$

$$U_q(R_p^b,R_q^b,R_l^*)+\frac{\delta_q}{1-\delta_q}U_q(\tilde{R}_p,\tilde{R}_q,R_l')\le\frac{1}{1-\delta_q}U_q(R_p^*,R_q^*,R_l^*)$$

$$[1+\delta_p]U_p(R_p^*,R_q^*,R_l^*)\ge U_p(R_p^b,R_q^b,R_l^*)+\delta_pU_p(R_p^*,R_q^*,R_l^b)$$

$$[1+\delta_q]U_q(R_p^*,R_q^*,R_l^*)\geq U_q(R_p^b,R_q^b,R_l^*)+\delta_q U_q(R_p^*,R_q^*,R_l^b)$$

$$U_p(R_p^*,R_q^*,R_l^b)+\frac{\delta_p}{1-\delta_p}U_p(R_p^*,R_q^*,R_l^*)\geq\frac{1}{1-\delta_p}U_p(\tilde{R}_p,\tilde{R}_q,R_l')$$

$$U_q(R_p^*,R_q^*,R_l^b)+\frac{\delta_q}{1-\delta_q}U_q(R_p^*,R_q^*,R_l^*)\geq\frac{1}{1-\delta_q}U_q(\tilde{R}_p,\tilde{R}_q,R_l')$$

$R_q{}^b$ and $R_p{}^b$ denote the reduction levels of a breaching subcoalition. $\tilde{R}_p$ and $\tilde{R}_q$ are reduction levels which are self-enforcing between the two parties in the subcoalition. Condition 4 collects the arguments of Conditions 1-3 for all possible subcoalitions.

However, the concept of coalition-proofness according to Bernheim, Peleg and Whinston (1987) and its reformulation by Condition 4 do not cover all aspects of subcoalitions because they focus exclusively on the joint breach of an agreement. In addition, every potential subcoalition has a commitment problem. If one country refuses any cooperation, the other two countries are still able to reach a bilateral agreement. The result in reductions of a bilateral agreement is anticipated by the third country and determines its gains from refusing cooperation. Condition 5 completes the constraints imposed by subcoalitions and gives a precondition for Condition 1 and Condition 3 which assumed that all countries want to form the grand coalition. Let $\tilde{R}_{-l}$ denote the reduction levels of the two other countries if country l stays away from the agreement. $\tilde{R}_{-l}$ is determined by the subcoalition's agreement because the remaining two countries cannot commit themselves not to realize possible cooperation gains.

Condition 5: *If one country wants to stay away from the agreement, the other two countries will cooperate if cooperation improves on the purely non-cooperative outcome. If more than one country wants to stay away from the agreement, the two countries which benefit most from a subcoalition's agreement negotiate away from the purely non-cooperative outcome. The agreement between these two countries determines the utility of the country which stays away from the agreement. If every country prefers a subcoalition with a country which prefers a subcoalition with the third country, a subcoalition will be formed but the subcoalition's parties are undetermined.*

(C5) $\forall\{p,q\}\in\{\{i,j\},\{j,k\},\{i,k\}\},\forall l\in\{i,j,k\setminus p,q\},$

$$\forall\tilde{R}_{-l}=\left[\tilde{R}_p,\tilde{R}_q\right]\in\left\{\left[R_p^*,R_q^*\right]\middle| R_l=R_l'\right\}:$$

$$A=\{i,j,k\}$$

if $\quad \forall l\in\{i,j,k\}: U_l\left[R_l'',\tilde{R}_{-l}\right]\leq U_l\left[R_l^*,R_{-l}^*\right],$

$$A=\{p,q\}$$

if $\quad U_l\left[R_l'',\tilde{R}_{-l}\right]>U_l\left[R_l^*,R_{-l}^*\right],$

$$U_p\left[R_p'',\tilde{R}_{-p}\right]\leq U_p\left[R_p^*,R_{-p}^*\right],$$

$$U_q\left[R_q'',\tilde{R}_{-q}\right]\leq U_q\left[R_q^*,R_{-q}^*\right],$$

$$A=\{p,q\}$$

if $\quad U_l\left[R_l'',\tilde{R}_{-l}\right]>U_l\left[R_l^*,R_{-l}^*\right],$

$$U_p\left[R_p'',\tilde{R}_{-p}\right]>U_p\left[R_p^*,R_{-p}^*\right],$$

$$U_q\left[R_q'',\tilde{R}_{-q}\right]>U_q\left[R_q^*,R_{-q}^*\right],$$

$$U_p\left[\tilde{R}_p,\tilde{R}_q,R_l''\right]\geq U_p\left[\tilde{R}_p,R_q'',\tilde{R}_l\right],$$

$$U_q\left[\tilde{R}_p,\tilde{R}_q,R_l''\right]\geq U_q\left[R_p'',\tilde{R}_q,\tilde{R}_l\right].$$

A denotes the set of countries which join a multilateral environmental agreement. R_l'' gives the non-cooperative reduction level of country l for the case that the other two countries form a subcoalition. R_l'' falls short of R_l' in the case of non-orthogonal reaction functions. Note that (C5) is incomplete in describing Condition 5 because it does not include the ambiguity case.

All five conditions can restrict the scope for multilateral environmental agreements considerably. The following section will demonstrate a specific model which allows only a subcoalition of two countries to join an environmental agreement.

3. Self-Enforcing Cooperation in a Three-Country-Model

Section 2 has developed five conditions to be met by multilateral environmental agreements. This section will employ a specific model in order to emphasize the role of domestic institutional settings for the performance of an international agreement. Differences in institutional settings are indicated by differences in discount factors. A high discount factor mirrors "institutional toughness" of the potential signatory country. In order to develop the role of different discount factors, this section assumes identical cost and benefit functions:

$$(2) \qquad \forall l \in \{i,j,k\}: \qquad B_l = \alpha\left[R_i + R_j + R_k\right], C_l^0 = \frac{\beta}{2}R_l^2,$$

$$\alpha, \beta > 0.$$

Benefits are a linear function of the sum of reductions, costs are a quadratic function of domestic reductions. These functions imply orthogonal reaction functions and thereby let the reduction level for non-cooperation and a breach of the agreement coincide. The discount factors are assumed to differ:

$$(3) \qquad \delta_i = \delta_j = \delta > 0.5, \ \delta_k < 0.5.$$

Two countries exhibit a comparably high discount factor which signals a "tough" institutional setting. In these countries, long-run gains are given a significantly stronger weight than in country k. Country k is assumed to bear a strong domestic pressure on short-run issues. E.g., countries i and j could represent industrialized countries and county k's impatience could represent the pressure felt by a government of a developing country which is lacking economic prosperity.[3]

It is helpful to start the discussion of (2) and (3) for multilateral environmental agreements by considering the potential cooperation between only two of the three countries. The orthogonality of the reaction functions lets the result of a subcoalition's agreement coincide with the outside option of a subcoalition (see Condition 4) and the subcoalition's agreement if one country refuses to cooperate. Additionally, the functional form given by (2) has the convenient property that all three conditions imposed by weak renegotiation-proofness fall together for the potential cooperation between two countries (see Appendix A.1).

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3 The indicated values of the discount factors are not out of any empirical range because environmental agreements address periods which cover several years. In many cases, compliance can be verified not before a couple of years after the agreement was ratified, especially when environmental data are available only with a significant delay.

Note that the punishment device defined by Conditions 2 and 3 was somewhat arbitrary in specifying a one-period-investment which restarts cooperation. In general, a punishment device could also want a non-compliant country to invest n periods in providing the agreed-upon reduction level unilaterally before the other countries restart cooperation. An increasing n strengthens the power of the ex ante compliance constraint of Condition 2 but weakens the power of the ex post compliance constraint of Condition 3 because it decreases the incentive to invest into a restart of cooperation after a contract breach has occurred. For (2) and n = 1, both constraints have the same power and are thereby equalized. If a certain condition dominated the other conditions (as it is the case if n is not set unity), lowering n could make all countries better off, as an extremely biting constraint may restrict cooperation more than necessary. The paper does not consider strategic aspects of different n, but it should have become clear that n = 1 is an appropriate assumption for the specific model of this section.

According to weak renegotiation-proofness, $\tilde{R}_p$ and $\tilde{R}_q$ of two countries p and q, p,q ∈ {i,j,k}, have to fulfil

$$(4)\qquad R_p \geq \frac{\alpha}{\beta} + \frac{1}{\delta_q}\frac{\beta}{2\alpha}\left[\tilde{R}_q - \frac{\alpha}{\beta}\right]^2,$$

$$R_q \geq \frac{\alpha}{\beta} + \frac{1}{\delta_p}\frac{\beta}{2\alpha}\left[\tilde{R}_p - \frac{\alpha}{\beta}\right]^2.$$

(4) gives the conditions of weak renegotiation-proofness for a subcoalition with two parties p and q but does not determine the concrete outcome of the subcoalition's agreement. An additional assumption is necessary how cooperation gains are to be divided between the two countries. This paper will consider two variants of all possible sharing rules, equal split and maximal bargaining gains for one country.

According to (3), two cases have to be distinguished when evaluating the equal split results. In a first variant, assume that country i and country j bargain for a subcoalition's agreement. Equal split assumes that both countries' bargaining gains equalize:

$$(5)\qquad \{p,q\} = \{i,j\} \Rightarrow \quad \tilde{R}_i = \tilde{R}_j = \frac{2\alpha}{\beta}, \qquad \tilde{U}_i = \tilde{U}_j = \frac{3\alpha^2}{\beta}$$

Obviously, (5) implies identical reduction levels when an equal-split policy should be realized. Due to their institutional toughness, both countries are able to join an agreement which is optimal and self-enforcing for the subcoalition. This result does not hold if either country i or country j consider a subcoalition's agreement with country k. For example, any equal-split-policy between country i and country k produces

$$(6) \quad \{p,q\} = \{i,k\}: \qquad \tilde{R}_i = \tilde{R}_k = [1 + 2\delta_k]\frac{\alpha}{\beta},$$

$$\tilde{U}_i = \tilde{U}_k = \left[\frac{5}{2} + 2\delta_k - \frac{\delta_k^2}{2}\right]\frac{\alpha^2}{\beta}.$$

As country i and country j are perfect twins, (6) holds for {p,q} = {j,k} accordingly. Every agreement with country k suffers from the institutional weakness of this country. This assertion does even hold for many cases which enable country i (or country j) to realize its maximal bargaining gains:

$$(7) \quad \max_{R_i, R_k} U_i \qquad \text{s.t.} \qquad R_i = \frac{\alpha}{\beta} + \frac{1}{\delta_k}\left[R_k - \frac{\alpha}{\beta}\right]^2 \Rightarrow$$

$$\delta_k \leq 0.25: \quad \tilde{R}_i = \tilde{R}_k = [1 + 2\delta_k]\frac{\alpha}{\beta}$$

$$\tilde{U}_i = \left[\frac{5}{2} + 2\delta_k + \frac{\delta_k^2}{2}\right]\frac{\alpha^2}{\beta}$$

$$\delta_k > 0.25: \quad \tilde{R}_i = \left[1 + \left(\frac{\delta_k}{2}\right)^{1/3}\right]\frac{\alpha}{\beta}$$

$$\tilde{R}_k = \left[1 + (2\delta_k^2)^{1/3}\right]\frac{\alpha}{\beta}$$

$$\tilde{U}_i = \left[(2\delta_k^2)^{1/3} - \frac{1}{2}\left(\frac{\delta_k^2}{2}\right)^{2/3}\right]\frac{\alpha^2}{\beta}$$

Comparing $\tilde{U}_i$ in (6) and (7) shows that country i prefers an equal-split-policy with country j compared to the best policy with country k if

$$\delta_k < 2\sqrt{\frac{1}{27}} \approx 0.3849$$

holds. If country i (country j) is not able to realize a sufficiently large portion of the bargaining gains, country i (country j) prefers to form a subcoalition with country j (country i). Thus, the assumptions of (3) give a lot of evidence that country i and country j form a subcoalition. In an equal-split-setting, this subcoalition dominates the other two two-country-teams. If only two countries were allowed to cooperate, the best team would obviously include country i and country j because there is no scope for other subcoalitions in the case of equal split and only little scope in the case of policies which favor the more patient country. The remainder of this paper will therefore focus on the relevant outsider subcoalition which includes country i and country j. This gives a preliminary result for Condition 5 because it determines that the subcoalition {i,j} will be formed in cases when country k wants to stay away from the agreement.

One might wonder whether transfers can mitigate the compliance problems. Obviously, transfers between country i and j are not necessary because their equal-split-policy leads to optimal reduction levels for the subcoalition. Appendix A.2 gives a sketch of the proofs that transfers cannot help overcoming the compliance problems for a subcoalition of country i (country j) and country k. Both countries choose deliberately a zero transfer level for the equal-split-policy as well as for the best policy of country i (country j) because transfers involve sovereignty risks, too. E.g. assume that in addition to certain reduction duties a transfer payment from country i to country k is agreed-upon. Then, non-compliance of country k means not to fulfil its reduction duties but to take the transfer. Non-compliance of country i means not to fulfil its reduction duties and to refuse the transfer payment. The opposite holds if country k pays country i. Appendix A.2 employs the corresponding four compliance constraints to demonstrate the optimality of zero transfers.[4]

From the viewpoint of the grand coalition, the dominating role of the subcoalition of i and j implies

- that the reduction levels are determined by the subcoalition between i and j if cooperation is not possible in the grand coalition,

  i.e. $\tilde{R} = \left(\tilde{R}_i, \tilde{R}_j, \tilde{R}_k\right) = \left(\frac{2\alpha}{\beta}, \frac{2\alpha}{\beta}, \frac{\alpha}{\beta}\right)$

  (see Condition 5), and

- that the joint exploitation of a third country is apparently more attractive for the subcoalition of country i and country j (see Condition 4).

4 The complete proofs are available upon request. Note that transfers can play a role if cost and benefit functions differ. In this case, transfers serve for exploiting efficiency gains but not for ensuring compliance.

Assume that all countries have decided for cooperating in the grand coalition which splits cooperation gains equally. Assuming a grand coalition means that no country wants to stay away from the agreement and R'_{-l} determines the outside option for every country l. According to the identity of cost and benefit functions, equal split means equal reductions. Let $\hat{R}$ denote the identical reduction levels of each country in a grand coalition. (C1), (C2) and (C3) fall together if (2) and (3) hold. Then, a grand coalition demands

$$\text{(8a)} \quad R_j + R_k \geq \frac{2\alpha}{\beta} + \frac{1}{\delta_i}\frac{\beta}{2\alpha}\left[R_i - \frac{\alpha}{\beta}\right]^2,$$

$$R_i + R_k \geq \frac{2\alpha}{\beta} + \frac{1}{\delta_j}\frac{\beta}{2\alpha}\left[R_j - \frac{\alpha}{\beta}\right]^2,$$

$$R_i + R_j \geq \frac{2\alpha}{\beta} + \frac{1}{\delta_k}\frac{\beta}{2\alpha}\left[R_k - \frac{\alpha}{\beta}\right]^2.$$

to be fulfilled. (8a) can be developed similar to the arguments given in Appendix A.1 for the two-country-case. In this setting, country k's compliance constraint determines the individual reduction levels:

$$\text{(8b)} \quad \hat{R} = \frac{\alpha}{\beta}[1 + 4\delta_k],$$

$$\hat{U}_i = \hat{U}_j = \hat{U}_k = \frac{\alpha^2}{2\beta}[5 + 16\delta_k - 16\delta_k^2]$$

(8b) gives the utilities which are realized in a grand coalition with all countries. Now, two countries evaluate whether they are better off by jointly breaching the agreement in one period and founding a subcoalition for the following periods. Referring to the first line of (C4), country i (country j accordingly) will not deceive country k together with country j if

$$\text{(9)} \quad \frac{\alpha^2}{2\beta}[5 + 16\delta_k - 16\delta_k^2] \geq [1 - \delta_i]\left[\frac{2\alpha^2}{\beta} + \frac{\alpha^2}{\beta}(1 + 4\delta_k)\right] + \delta_i\frac{3\alpha^2}{\beta}$$

$$\Leftrightarrow \delta_k[1 - 2\delta_k + \delta_i] - \frac{1}{8} \geq 0$$

holds. (9) is not met by all combinations of $\delta_i = \delta_j$ and δ_k. If country k is extremely impatient, especially when δ_k falls of from 0.1, it can pay for i and j to deceive k jointly.

The assumption of a joint agreement breach of country i and country k gives a different constraint (see the first line of (C4)). Country i (country j accordingly) will not deceive country j (country i) together with country k if

$$(10)\quad \frac{\alpha^2}{2\beta}\left[5+16\delta_k-16\delta_k^2\right]\geq$$

$$[1-\delta_i]\left\{\alpha\left[(2+4\delta_k)\frac{\alpha}{\beta}+(1+4\delta_k)\frac{\alpha}{\beta}\right]-\frac{\alpha^2}{2\beta}[1+2\delta_k]^2\right\}$$

$$+\delta_i\frac{\alpha^2}{\beta}\left[2\delta_k-\frac{\delta_k^2}{2}\right]$$

$$\Leftrightarrow -4\delta_k+12\delta_k^2-5\delta_i-8\delta_i\delta_k-\delta_i\delta_k^2<0$$

holds. (10) is always fulfilled because $\delta_k>\delta_k^2$ and $\delta_i\delta_k>\delta_k^2$ leads to

$$12\delta_k^2-8\delta_i\delta_k-4\delta_k<0$$

which is a necessary and sufficient condition for (10). Thus, only country k is endangered to be exploited jointly by countries i and j. But even if this exploitation risk could be excluded, the implications of Condition 5 dominate the performance of the agreement. Condition 5 shapes the structure of the agreement because the high level of cooperation between i and j induces country k to stay away from any agreement. Note that

$$(11)\quad \forall l\in\{i,j,k\}:$$

$$U_l\left(\hat{R}_i,\hat{R}_j,\hat{R}_k\right)=\frac{\alpha^2}{2\beta}\left[5+16\delta_k-16\delta_k^2\right]<\frac{9}{2}\frac{\alpha^2}{\beta}$$

holds. $9/2\ \alpha^2/\beta$ is the Pareto-optimal level which an enforceable agreement specified. (11) states that incorporating the impatient country k implies utility levels which fall short of the Pareto-optimal ones. If country i (country j accordingly) decides to remain an outsider, it anticipates that country j (country i) and country k realize the subcoalition's reduction levels

$$\tilde{R}_j=\tilde{R}_k=[1+2\delta_k]\frac{\alpha}{\beta}$$

which gives country i a utility of

$$\tilde{U}_i=\frac{\alpha^2}{2\beta}[5+8\delta_k]<\frac{\alpha^2}{2\beta}\left[5+16\delta_k-16\delta_k^2\right]$$

This utility falls short from the utility in the grand coalition. Country i and country j do not prefer the outsider position but country k does. This is the second case mentioned in (C5). Country k will anticipate that country i and country j realize the subcoalition's reduction levels

$$\tilde{R}_i = \tilde{R}_j = \frac{2\alpha}{\beta}$$

which give country k a utility of

$$\text{(12)} \quad U_k = \frac{9}{2}\frac{\alpha^2}{\beta} > \frac{\alpha^2}{2\beta}\left[5 + 16\delta_k - 16\delta_k^2\right] = U_k\left(\hat{R}_i, \hat{R}_j, \hat{R}_k\right)$$

(12) proves that country k will always prefer to remain an outsider country. This result shapes the structure of the environmental agreement which includes only country i and country j. The model has demonstrated that Conditions 1 to 5, and especially Condition 5 which defines the role of coalitions for outside options, can severely restrict the scope for cooperation. If (2) and (3) hold, the multilateral environmental agreement is changed into a bilateral one. Accordingly, (2) and (3) imply

$$\text{(13)} \quad \left[R_i^*, R_j^*, R_k^*\right] = \left[\frac{2\alpha}{\beta}, \frac{2\alpha}{\beta}, \frac{\alpha}{\beta}\right]$$

if international environmental policies end up with the reduction game.

4. Transfers to the Outsider Country

The disappointing result of the last section is not necessarily the definite end of international environmental policies. Although only a subcoalition consisting of country i and country j is able to implement a joint reduction policy, further reductions are possible if the subcoalition's reduction policy is supplemented by transfer policies. This section assumes that the subcoalition founds a bilateral agency which organizes the transfers which the subcoalition pays for extra reductions of country k on behalf of both countries. The agency is assumed to be able to realize transfer policies which guarantee the maximal bargaining gains for the donor countries.[5] The agency is an institution founded by country i and country j and can be imagined as an organization which works according to strictly predetermined rules. These rules serve for commitment which enables the agency to reap the maximal bargaining gains from transfer policies. Note that this assumption is not a too unrealistic one when compared with international organizations like the World Bank and the Global Environmental Facilities which obviously have a strong bargaining position.

In addition to the strong bargaining position, international organizations founded to support countries do not merely reflect financial intermediaries. E.g., the Global Environmental Facilities do not only pay for environmental services but support and control specific environment-enhancing projects. Support is often given in kind. Support by in-kind transfers is a superior transfer scheme if transfer policies must be self-enforcing (Stähler, 1992, 1994). This section models these features of international organizations' transfer policies by considering different reduction technologies. It assumes that technologies can be varied steadily and steady variations can be indicated by a technology parameter λ. The voluntarily provided reduction level α/β will be produced by a technology with $\lambda = 0$ which carries the lowest reduction costs. Basing transfer policies on a certain technology λ produces additional costs Δ in country k:

$$(14) \quad \Delta(\rho) = \frac{\beta}{2}\left[e^{a\lambda}\rho + \frac{\alpha}{\beta}\right]^2 - \frac{\alpha^2}{2\beta}, \lambda \geq 0, a>0.$$

ρ denotes the additional agreed-upon reductions of country k. A technology which is associated with a higher λ carries higher organizational and technological costs. These higher costs are due to an increasing degree of direct control and influence. The option of direct

5 Note that country k's incentive to remain an outsider country is strengthened if country k anticipates transfers. However, assuming anticipation by the recipients and solving the models backwards does not change the results of this paper. Even if anticipation induces i or j to prefer staying away from the agreement, too, Condition 5 has specified that these countries would renegotiate away from the purely non-cooperative outcome.

control and influence increases costs and decreases the incentives for a transfer agreement's breach.

A breach of a transfer agreement means to take the transfers but not to provide the additional agreed-upon reductions. With an increasing λ, the transfer is changed from a monetary into an in-kind transfer, thereby influencing the non-compliance option. On the one hand, in-kind transfers guarantee that a certain degree of reductions is realized independent of compliance. On the other hand, in-kind transfers have a lower value for the recipient when recipients want to breach the agreement because in-kind transfers can be used only for specific purposes and incur retrading costs. Additionally, a certain part of the transfer may be withdrawn by the donor in the case of non-compliance if the agency controls the project. Let ρ' and T' denote the degree of reductions which is realized even in the case of non-compliance and the recipient's value of transfers if he breaches the transfer agreement, respectively. Both terms depend on λ in that a higher λ induces a higher ρ' and a lower T':

$$(15)\quad \rho' = \left[1 - e^{-b\lambda}\right]\rho, \qquad T' = e^{-c\lambda}T, \quad b,c>0.$$

T denotes the value of transfers when transfers are employed according to the agreement. On the donors' side, a simple rule can make the agreement self-enforcing between country i and country j. Assume that the equal-split-policy is also applied on joint transfer policies and both countries carry the transfer payments equally. The agreement with country k may specify that the agreed-upon reductions have only to be provided if both countries fulfil their transfer obligations and thereby enable the agency to transfer the corresponding resources. This specification rules out any incentive to deviate from the individual transfer payments and allows for focusing on the relationship between the two donors and the recipient.

Let ρ^* denote the degree of country k's additional reductions according to a transfer agreement. T^* denotes the agreed-upon transfers. According to the concept of weak renegotiation-proofness, three conditions impose restrictions on possible transfer policies.

Condition 6: *The long-run gains from the transfer agreement must not fall short of breaching the agreement in one period and no cooperation in all following periods.*

$$(C6)\quad \frac{1}{1-\delta_k}\left[T^* - \Delta(\rho^*) + \alpha\rho^*\right] \geq T' = e^{-c\lambda}T^*$$

$\alpha\rho^*$ are the additional benefits of the recipient from its own extra reductions. (C6) gives the basic condition for cooperation. No cooperation means no transfers and no additional reductions. The other two conditions associated with weak renegotiation-proofness demand to specify how country k can restart cooperation. (15) guarantees for a strictly positive λ that a certain degree of additional reductions will be realized independent of compliance. (C7) and (C8) assume that the donors want any deviance to be counterbalanced by additional reductions

(16) $$\rho^{+} = \rho^{*} - \rho' = e^{-b\lambda}\rho^{*}.$$

Country k is able to restart cooperation after a breach by providing the difference between realized and agreed-upon extra reductions.

Condition 7: *Given that a non-compliant country k wants to restart cooperation as soon as possible, the gains from the transfer agreement must not fall short of breaching the transfer agreement in one period and restarting cooperation by providing ρ^{+} unilaterally.*

(C7) $$\begin{aligned}[1+\delta_k][T^{*} - \Delta(\rho^{*}) + \alpha\rho^{*}] &\geq T' - \delta_k\Delta(\rho^{+}) + \alpha\rho^{+} \\ &= e^{-c\lambda}T^{*} - \delta_k\Delta(e^{-b\lambda}\rho^{*}) + \alpha e^{-b\lambda}\rho^{*}\end{aligned}$$

Condition 8: *After country k has breached the transfer agreement, it wants to restart cooperation as soon as possible.*

(C8) $$\begin{aligned}&-\Delta(\rho^{+}) + \alpha\rho^{+} + \frac{\delta_k}{1-\delta_k}[T^{*} - \Delta(\rho^{*}) + \alpha\rho^{*}] \geq 0 \\ \Leftrightarrow\ &\frac{\delta_k}{1-\delta_k}[T^{*} - \Delta(\rho^{*}) + \alpha\rho^{*}] \geq \Delta(e^{-b\lambda}\rho^{*}) + \alpha e^{-b\lambda}\rho^{*}\end{aligned}$$

Conditions 6 to 8 can be rewritten as minimum transfer conditions:

(C6)' $$T^{*} \geq \frac{\Delta(\rho^{*}) - [e^{-b\lambda} + \delta_k(1-e^{-b\lambda})]\alpha\rho^{*}}{1-[1-\delta_k]e^{-c\lambda}},$$

(C7)' $$T^{*} \geq \frac{[1+\delta_k]\Delta(\rho^{*}) - \delta_k\Delta(e^{-b\lambda}\rho^{*}) - [e^{-b\lambda} + \delta_k(1-e^{-b\lambda})]\alpha\rho^{*}}{1+\delta_k - e^{-c\lambda}},$$

(C8)' $$T^{*} \geq \Delta(\rho^{*}) - \alpha\rho^{*} + \frac{[1-\delta_k][\Delta(e^{-b\lambda}\rho^{*}) - \alpha e^{-b\lambda}\rho^{*}]}{\delta_k}.$$

If the least-cost-technology is chosen, i.e. $\lambda = 0$, all conditions coincide in that

$$(17) \quad T^* \geq \frac{\Delta(\rho^*) - \alpha\rho^*}{\delta_k}$$

must hold.

The international agency which organizes transfer policies on behalf of country i and country j has been assumed to maximize the possible bargaining gains for the donors. The objective of the agency is to maximize the difference between the Lindahlian utility of additional reductions and the transfers necessary to guarantee compliance:[6]

$$(18) \quad \max_{\rho^*,\lambda} \Omega \qquad \text{s.t.} \quad \Omega = 2\alpha\rho^* - T^*, (C6)', (C7)', (C8)', \rho^* \geq 0, \lambda \geq 0.$$

(18) gives the maximization problem for a Stackelberg leader who predetermines the degree of additional reductions and the technology.

The solution of this maximization problem could be developed along the lines of the Kuhn-Tucker-Theorem. Instead, the remainder of this section will demonstrate that a maximizing agency does not always chose the lowest-cost-technology. The proof will be developed by contradiction. Assume that the least-cost-technology $\lambda = 0$ does always maximize the Lindahlian utility of the donor countries. In this case, (17) holds. For a fixed $\lambda = 0$, the solution for (18) is given by

$$(19) \quad \frac{\partial\Omega}{\partial\rho^*}(\lambda = 0) = 2\alpha - \frac{\partial T^*}{\partial\rho^*}(\lambda = 0) = 0 \Rightarrow \rho^* = 2\delta_k \frac{\alpha}{\beta}.$$

$\lambda = 0$ is optimal if

$$(20) \quad \begin{aligned} &\frac{\partial\Omega}{\partial\lambda}\left(\lambda = 0, \rho^* = 2\delta_k \frac{\alpha}{\beta}\right) \leq 0 \\ &\Rightarrow \frac{\partial T^*}{\partial\lambda}\left(\lambda = 0, \rho^* = 2\delta_k \frac{\alpha}{\beta}\right) \geq 0 \end{aligned}$$

holds. Let T_1, T_2 and T_3 denote the transfer levels which equalize (C6)', (C7)' and (C8)'. Differentiating T_1, T_2 and T_3 with respect to λ, setting $\lambda = 0$ and $\rho = 2\delta_k\alpha/\beta$ gives the following formulas for a marginal change away from the least-cost technology.

6 For obvious reasons, both country i and country j prefer a joint transfer policy compared to introducing transfer policies separately. The condition that transfer payments should not fall of from the additional costs is dominated by all three conditions.

$$(21)\quad \frac{\partial T_1}{\partial \lambda}\left[\lambda = 0, \rho^* = 2\delta_k \frac{\alpha}{\beta}\right] = \frac{2\alpha^2}{\beta}\{a[1+\delta_k] + b[1-\delta_k] - c[1+\delta_k]\}$$

$$(22)\quad \frac{\partial T_2}{\partial \lambda}\left[\lambda = 0, \rho^* = 2\delta_k \frac{\alpha}{\beta}\right] = \frac{2\alpha^2}{\beta}\{a[2\delta_k + 1] + b[2\delta_k^2 + 1] - c\}$$

$$(23)\quad \frac{\partial T_3}{\partial \lambda}\left[\lambda = 0, \rho^* = 2\delta_k \frac{\alpha}{\beta}\right] = \frac{2\alpha^2}{\beta}\{a[2\delta_k + 1] - 2\delta_k b[1-\delta_k]\}$$

(22) and (23) reveal the ambiguous role of b which indicates the degree of reductions pushed through by a technology in the case of non-compliance. Consider for example an increase of b which decreases the costs of restarting cooperation. On the one hand, lower costs of restarting cooperation makes non-compliance more attractive because the benefits from breaching the agreement and restarting cooperation are increased (see C7)). On the other hand, ex post compliance is made more attractive after k has breached the transfer agreement because lower costs of restarting cooperation increase the incentive to restart cooperation as soon as possible.

Optimality of $\lambda = 0$ demands that at least one of the derivatives, i.e. either (21), (22) or (23) is non-negative. If

$$(24)\quad c > a + b\frac{1-\delta_k}{1+\delta_k}, \qquad c > a[2\delta_k + 1] + b[2\delta_k^2 + 1],$$

$$b > a\frac{2\delta_k + 1}{2\delta_k[1-\delta_k]}$$

hold, (21), (22) and (23) are all negative and contradict the assumption of an optimal $\lambda = 0$. In this case, the utility of the donor countries could be improved on by increasing λ. For example, (24) is met by $a = 0.1$, $b = 0.4$, $c = 0.8$ and $\delta_k = 0.4$. (24) proves that there is some scope for optimal transfer policies which do not employ the least-cost-technology. When transfer policies are endangered by non-compliance of the recipient, switching to a cost-inferior technology may increase compliance incentives and thereby overcompensate for higher costs.

5. Summary and Conclusions

This paper has discussed the implications of some basic conditions which multilateral environmental agreements should meet in the three-country-case. A specific model has shown that cooperation can be restricted on two countries when one country lacks institutional toughness. The concepts of renegotiation- and coalition-proofness as well as an extension which defines the role of coalitions for outside options can explain the participation endogenously. Referring to the model of Section 2, it is not surprising that the industrialized countries are likely to go ahead with respect to a joint environmental policy.

The paper has also shown that a subcoalition's agreement is not necessarily the end of international environmental policies. A subcoalition can introduce transfer policies in order to buy some extra reductions of the outsider country. The model of Section 4 assumed a Stackelberg leadership of the donor countries through an agency which specifies the degree of extra reductions and the reduction technology. Technologies differ with respect to costs and non-compliance options in that higher costs are attributed to those technologies which are given in kind. Section 4's model has demonstrated that optimal transfer policies may employ other than least-cost technologies because the benefits of decreasing non-compliance incentives may overcompensate for higher costs. Thereby, the model could explain transfer policies of multilateral organization, e.g. the Global Environmental Facilities. Both features, the endogenous determination of participating countries and the role of transfer policies, seem to be backed by empirical evidence.

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Appendix A.1

For the two-country cooperation, the ousider country l chooses the reduction level α/β which is also the non-cooperative reduction level and the breach level for both country p and country q. Condition 1 demands

(A.1-1)
$$\frac{1}{1-\delta_p}\left\{\alpha\left[\tilde{R}_p+\tilde{R}_q+\frac{\alpha}{\beta}\right]-\frac{\beta}{2}\tilde{R}_p^2\right\}\geq\frac{\alpha^2}{2\beta}+\alpha\tilde{R}_q+\frac{\alpha^2}{\beta}+\frac{\delta_p}{1-\delta_p}\frac{5}{2}\frac{\alpha^2}{\beta},$$

$$\frac{1}{1-\delta_q}\left\{\alpha\left[\tilde{R}_p+\tilde{R}_q+\frac{\alpha}{\beta}\right]-\frac{\beta}{2}\tilde{R}_q^2\right\}\geq\frac{\alpha^2}{2\beta}+\alpha\tilde{R}_p+\frac{\alpha^2}{\beta}+\frac{\delta_q}{1-\delta_q}\frac{5}{2}\frac{\alpha^2}{\beta}.$$

Condition 2 demands

(A.1-1)'

$$\left[1+\delta_p\right]\left\{\alpha\left[\tilde{R}_p+\tilde{R}_q+\frac{\alpha}{\beta}\right]-\frac{\beta}{2}\tilde{R}_p^2\right\}\geq\frac{\alpha^2}{2\beta}+\alpha\tilde{R}_q+\frac{\alpha^2}{\beta}+\delta_p\left[\alpha\tilde{R}_p-\frac{\beta}{2}\tilde{R}_p^2+\frac{2\alpha^2}{\beta}\right]$$

(A.1-2)'

$$\left[1+\delta_q\right]\left\{\alpha\left[\tilde{R}_p+\tilde{R}_q+\frac{\alpha}{\beta}\right]-\frac{\beta}{2}\tilde{R}_q^2\right\}\geq\frac{\alpha^2}{2\beta}+\alpha\tilde{R}_p+\frac{\alpha^2}{\beta}+\delta_q\left[\alpha\tilde{R}_q-\frac{\beta}{2}\tilde{R}_q^2+\frac{2\alpha^2}{\beta}\right]$$

Condition 3 demands

(A.1-1)"
$$\alpha\tilde{R}_p-\frac{\beta}{2}\tilde{R}_p^2+\frac{2\alpha^2}{\beta}+\frac{\delta_p}{1-\delta_p}\left\{\alpha\left[\tilde{R}_p+\tilde{R}_q+\frac{\alpha}{\beta}\right]-\frac{\beta}{2}\tilde{R}_p^2\right\}\geq\frac{1}{1-\delta_p}\frac{5}{2}\frac{\alpha^2}{\beta}$$

(A.1-2)"
$$\alpha\tilde{R}_q-\frac{\beta}{2}\tilde{R}_q^2+\frac{2\alpha^2}{\beta}+\frac{\delta_q}{1-\delta_q}\left\{\alpha\left[\tilde{R}_p+\tilde{R}_q+\frac{\alpha}{\beta}\right]-\frac{\beta}{2}\tilde{R}_q^2\right\}\geq\frac{1}{1-\delta_q}\frac{5}{2}\frac{\alpha^2}{\beta}$$

Solving for $\tilde{R}_p$ and $\tilde{R}_q$ in (A.1-1), (A.1-1)', (A.1-1)" and (A.1-2), (A.1-2)', (A.1-2)", respectively, gives (4).

Appendix A.2

Let X represent transfers which are paid from country i to country k. The introduction of transfers changes the net utilities according to

(A.2-1) $$\pi_i = U_i(R_i, R_j, R_k) - X,$$

$$\pi_j = U_j(R_i, R_j, R_k) + X.$$

As mentioned in the text, transfer payments are subject to sovereignty risks, too. The compliance constraints are supplemented by X-terms and differ with respect to the donor's constraint and the recipient's constraint. Along the lines of Appendix A.1, two cases have to be distinguished:

(A.2-2) $$\tilde{X} \geq 0 \Rightarrow \quad \text{(a)} \quad \tilde{R}_i \geq \frac{\alpha}{\beta} + \frac{1}{\delta_k}\frac{\beta}{2\alpha}\left[\tilde{R}_k - \frac{\alpha}{\beta}\right]^2 - \frac{\tilde{X}}{\alpha},$$

$$\text{(b)} \quad \tilde{R}_k \geq \frac{\alpha}{\beta} + \frac{1}{\delta_i}\frac{\beta}{2\alpha}\left[\tilde{R}_i - \frac{\alpha}{\beta}\right]^2 + \frac{1}{\delta_i}\frac{\tilde{X}}{\alpha},$$

(A.2-3) $$\tilde{X} \leq 0 \Rightarrow \quad \text{(a)} \quad \tilde{R}_i \geq \frac{\alpha}{\beta} + \frac{1}{\delta_k}\frac{\beta}{2\alpha}\left[\tilde{R}_k - \frac{\alpha}{\beta}\right]^2 - \frac{1}{\delta_k}\frac{\tilde{X}}{\alpha},$$

$$\text{(b)} \quad \tilde{R}_k \geq \frac{\alpha}{\beta} + \frac{1}{\delta_i}\frac{\beta}{2\alpha}\left[\tilde{R}_i - \frac{\alpha}{\beta}\right]^2 + \frac{\tilde{X}}{\alpha}.$$

$\tilde{X}$ denotes the agreed-upon transfers from country i to country k ($\tilde{X} < 0$ indicates transfers from country k to country i). When bargaining gains have to be split equally, π_i must equalize π_k:

(A.2-4) $$\pi_i = \pi_k \Rightarrow \qquad X = \frac{\beta}{4}\left[R_k^2 - R_i^2\right].$$

The best equal-split-policy is the solution of

(A.2-5) $$\max \Pi = \pi_i + \pi_k \qquad \text{s.t.} \quad X = \frac{\beta}{4}\left[R_k^2 - R_i^2\right], \text{(A.2-2), (A.2-3).}$$

Inserting the four compliance constraints into the maximization problem demonstrates that the first-order conditions give minima. The maxima are the corner solutions associated with zero transfer levels.

If country i is able to reap the maximal bargaining gains, the Kuhn-Tucker-approach can be applied on either

(A.2-6) $\max\limits_{R_i, R_k, X} \pi_i$ s.t. (A.2-2b) or

(A.2-7) $\max\limits_{R_i, R_k, X} \pi_i$ s.t. (A.2-3b).

Both approaches give an optimal zero transfer level.