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VOLUNTARY COMMITMENT TO ENVIRONMENTAL PROTECTION: A BOUNDED RATIONALITY APPROACH

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Abstract: Global environmental protection is characterized as a public good. In contrast to the national level where the state is able to regulate external effects, there is a lack of supranational institutions which have enough power to force countries to reduce pollution levels. In spite of the free-riding problem it can nevertheless be observed that countries sometimes commit themselves to contribute to the public good 'environmental protection'. The case of the Kyoto protocol for global CO_2 reduction demonstrates that some countries make substantial volunatry contributions, but others do not or on a much less level. The paper provides a game-theoretic explanation how the free-riding-problem can be overcome to some extent by voluntary cooperative behavior. It is analysed under which conditions free-riding countries can be motivated to make at least small pollution reduction efforts.

Keywords: global environmental policy, public good, voluntary cooperation, bounded rationality, game theory.

JEL-Classification: C72, D70, Q58

1 INTRODUCTION

In standard environmental economics pollution is characterized as an external effect of economic activity. This means that the welfare of other subjetcs is affected by these activities and that the effects are not compensated via the price system. Therefore, the price system is incomplete and leads to an inefficient allocation of goods and factors as well as to a loss of welfare. A reduction of pollution has then the characteristics of a public good: All subjects benefit from better environmental quality in a non-rivalry way and nobody can be disclosed from the benefits. On a national level the state is an institution which has the power to control pollutive acitivities, either by forcing the national pollutants (technological restrictions, quantitative limitations) or by incorporating external costs into the price system (environmental taxes or tradable pollution rights). Such policies are seen as appropriate answers to the market failure.

Unfortunatley, many environmental problems like the emission of the greenhouse gas CO_2 are global problems. A reduction of greenhouse gas emissions is then a contribution to a global public good. Moreover, an unilateral reduction by one country will have only marginal ecological effects and henceforth little benefits for the country itself while its reduction costs are very high. Only if a critical mass of countries make substantial pollution reduction efforts there is a significant positive effect. Due to the public good property the free-riding problem arises. There is no supranational institution which has enough power to force national governments to contribute to the public good or to establish a global incentive compatible mechanism of pollution control. Nevertheless, in the past many environmental contratcs between countries or at least declarations of intent have been made. This is remarkable, since deviations from the announced policy or violations of contracts will hardly lead to substantial sanctions. From a classical game-theoretic point of view contracts or declarations without powerful external institutions have no sufficient commitment power (see e.g. Böhringer/Vogt (2003) for a critical assessment of the Kyoto protocol). But nevertheless, some of them seem to work.

Classic game theoretic explanations for cooperation in a dilemma situation like the public good game are not very convincing in the context of global environmental protection. Approaches like the Folk theorem results or stratgic commitments as reputation signals always require repeated games and/or special assumptions about asymmetric information. In real world situations countries interact repeatedly, but each time in a different context with different information conditions including scientific knowledge. Especially there are no convincing explanations for the empirically relevant *co-existence* of cooperative and free-riding behavior. Hence, the theory of repeated games seem to be of limited use for analysing international environmental agreements. Furthermore, there is a lot of experimental evidence that agents do not behave according to the rational man paradigm. In experimental public good games and bargaining games there is robust evidence that people make substantial voluntary contributions and seem to be guided by fairness and reciprocity norms rather than rational opportunism (cf. Ledyard (1995), Keser (2002)). It seems to be promising to use game-theoretic concepts on the basis of bounded rationality to explain this kind of behavior and to apply them to the problem of international contracts about environmental protection.

The paper ist strucured as follows: Chapter 2 briefly reviews the basic game-theoretic concepts which account for boundedly rational decision behavior. In chapter 3 the general structure of the public good game is presented as a model for the contribution to global pollution reduction. Different cases of games with three countries are explicetly analyzed in chapter 4. Depending on the parametrization it is shown under which conditions voluntary contributions – guided by reciprocity norms or by rational imitation of reciprocity – occurs and can eventually co-exist with free-riding behavior. Chapter 5 summerizes the results and briefly discusses some policy implications.

2 A gAme-theoretic concept for bounded rationality

It is often claimed that decision behavior should no longer a priori identified with expected utility maximizing as it is the usual notion or rationality in economics (cf. Conlisk (1996), Selten (1990)). In a strategic context pure rational behavior can be characterized by choosing the best response to the expected decisions of all other players. Let S_i be the strategy space of player $i = 1, ..., n$ with $s_i \in S_i$ as his strategy, let $s_{-i} = (s_1, ..., s_{i-1}, s_{i+1}, ..., s_n)$ the strategy vector of all players except i, and $u_i(s_i, s_{-i})$ denotes the payoff function. Then

$$s_i^* \in \arg\max_{s_i \in S_i} u_i(s_i, s_{-i}^e) = f^{br}(s_{-i}^e)$$

is the best response map. A Nash equilibrium is a strategy profile (s_i^*, s_{-i}^*) where all agents play he best response and where the realized and expected decisions are identical. We generalize the approach by assuming that payoff maxizing is only *one* possibility to respond to the expected decisions of other players. More generally, $s_i \in f_i(s_{-i}^e)$ describes the way how player i responds to s_{-i}^e. The function (or correspondence) f_i is called a *behavioral rule* and it characterizes the pattern, *how* decisions are made. Such patterns emerge due to habit formation, social norms, specific cognitive concepts etc., and they have to be defined on the basis of empirical evidence. An equilibrium requires that behavior must not depend on contrafactual expectations, and that every player decides in full accordance with the adopted pattern of decision making f_i. An appropriate notion of equilibrium is a strategy vector (s_i^*, s_{-i}^*) with $s_i^* \in f_i(s_{-i}^e)$ and $s_i^e = s_i^*$ for all $i = 1, ..., n$ (for details cf. Pasche (2001)). Such a strategy vector is defined as a *behavioral equilibrium*: All players have consistent expectations and make decisions according to their adopted behavioral pattern. It has to be noted that the Nash equilibrium is a refinement of a behavioral equilibrium where all players adopt the best response rule $f_i = f^* \ \forall i$. Since each behavioral equilibrium depends on the behavioral rules which governs the decision making process, the equilibrium can also be denoted as $(s_1^*(f_1), ..., s_n^*(f_n))$. This means that the distribution of rules *induces* a behavioral equilibrium. However, the existence and uniqueness of such an equilibrium is not ensured. In the present context of complete information a behavioral equilibrium requires that the rules are Common Knowledge. The more complicated case of uncertainty about the rule type of other players is not considered in this paper.

One main problem of modelling boundedly rational behavior is the danger of considering complete *aribtrary* behavioral patterns, based on arbitrary assumptions (see Rubinstein (1998), p.4). Some of the behavioral hypotheses may have good descriptive properties but the explanatory power can be questionable. To escape from arbitrareness in considering rules f_i it has to be explained *why* players only adopt certain behavioral rules. For this reason we assume that actual decision behavior is governed by fixed rules, but that the rules themselves may change in the long run by individual learning or some kind of adaption processes. Individual learn, how to make (good) decisions (see, again, Rubinstein (1998), p.4). Furthermore, we assume that due to the adaption process only those rules are adopted which have a good performance, measured by expected equilibrium payoffs. Good performing rules are more likely to be adopted than poor performing ones. In the long run we then can identify rule profiles $(f_1^*, ..., f_n^*)$ (implying specific behavioral equilibria, if they exist) where no player can benefit from adopting another rule. Let F be the set of all feasible rules. Then $(f_1^*, ..., f_n^*)$ is called an *equilibrium rule profile* if

$$f_i^* \in \arg\max_{f_i \in F} u_i(s_1^*(f_1^*), ..., s_i^*(f_i), ..., s_n^*(f_n^*)) \quad \forall i,$$

where $(s_i^*(\cdot), s_{-i}^*(\cdot))$ is the induced behavioral equilibrium. This is equivalent to a Nash equilibrium on the level of rules instead of strategies. Norms, habits or other determinants of actual decision behavior – and even distributions of heterogeneous determinants – are not presupposed but endogeneous outcomes of equilibrium profiles.

The concept of equilibrium profiles serves as a selection device: It identifies 'justifiable' rules among a large variety F, and it is able to derive the specific conditions under which certain rules will be adopted and others not. A boundedly rational rule f_i can economically be justified as being a part of an equilibrium rule profile. This implies that it is not beneficial for each agent to adopt another decision pattern like payoff maximization (f^{br}) because this would induce a different behavioral equilibrium with lower equilibrium payoffs. If an equilibrium profile is interpreted as the long run outcome of an evolutionary adaption process it is remarkable that rational maximizing behavior generally cannot be justified as the unique dominant best performing behavioral pattern, as it was argued by Alchian (1950). Moreover it can be the case that – depending on the context – equilibrium distributions of diffrent rules may exist even if agents are assumed to be identical.

3 THE PUBLIC GOOD GAME: VOLUNATRY CONTRIBUTIONS AND FREE-RIDING

We apply the methodology of chapter 2 to a public good game. It is assumed that n players make contributions to a public good $c_i \in [0, a_i], i = 1, ..., n$ where $a_i > 0$ is the status quo pollution of country i. This implies that all other $n - 1$ players can not be disclosed from the benefits and that there is no rivalry in 'consuming' the good. A simple but appropriate payoff function can be written as

$$u_i = -c_i + \beta_i \sum_{i=1}^{n} c_i. \tag{1}$$

with $\beta_i \in [a_i / \sum_i a_i, 1]$ as the marginal return of contribution. If $\beta_i > 1$ would hold true then there is no dilemma situation since each country would benefit from its own (full) contribution $c_i = a_i$ regardless of the other player´s decisions. In case of $\beta < a_i / \sum_i a_i$ the player would never have a positive payoff even if all player make full contributions. Without loss of generality we normalize $\sum_i a_i = 1$ so that $a_i \in [0, 1]$. Different parameters a_i account for the possibility that agents may have different opportunities to contribute. In case of global pollution reduction a large emitter of greenhouse gases is able to make quantitatively larger contributions than a small emitter. The parameter β_i can also be country-specific. It is reasonable to argue that countries with very high opportunity costs of emission reduction will have lower values of β_i. Moreover, it is possible that countries are differently affected by the external effects of pollution, e.g.

countries may more or less suffer from the greenhouse effect. This can also be expressed by different β_i.

It is obvious that the solution of maximizing (1) is $c_i = 0$ which is the dominant strategy. This means that free-riding is the unique best response to the decisions of other players. The Nash solution $c_i = 0 \; \forall i$ is Pareto inferior because all players would benefit from full contributions $c_i = a_i \; \forall i$. As a first step we identify rational or 'opportunistic' decision making as a behavioral rule f^o with

$$c_i = f^o(c_{-i}) = 0. \tag{2}$$

In experimental games it is observed that agents are neither strictly opportunistic, nor they are unconditional cooperative, friendly, or fair. They behave rather friendly, cooperative and fair *conditional* to the (expected) behavior of other players. This phenomenon can be described as a *reciprocity norm.* In the present case we have a multiple agent game. We assume that reciprocity-guided agents (countries or governments) will make positive investments in the public good according to the average (relative) contributions of the other players $1/(n-1)\sum_{j\neq i}(c_j/a_j)$. A simple version of such reciprocal behavior is given by

$$c_i = \frac{a_i}{n-1}\sum_{j\neq i}\frac{c_j}{a_j}$$

implying that the contribution level equals the average contribution of all other players. However, this simple reciprocity rule has two severe shortcomings: (a) If all players adopt this rule there is a broad continuum of behavioral equilibria within the range $c_i^* \in [0, a_i]$ with $c_i/a_i = c_j/a_j \forall i, j$. It is an open question which equilibrium is selected. Furthermore, each equilibrium can easily been disturbed by small (stochastic) deviations because all agents would immediately respond to the deviation. (b) The presence of only one opportunistic free-rider even in a large population of players would reduce the equilibrium space to the unique solution $c_i = 0 \; \forall i$. In case of an arbitrary small uncertainty about the rule type of other players it is very unlikely to establish a solution with positive contributions.

A much more robust reciprocity rule f^r is obtained if a *base rate of cooperation* b is introduced which is assumed to be the same for all players:

$$c_i = b + \frac{(a_i - b)}{n-1}\sum_{j\neq i}\frac{c_j}{a_j} = f^r(s_{-i}), \tag{3}$$

If no player j makes a positive contribution to global pollution reduction the reciprocity rule implies $c_i = b$ where $b > 0$ may be very small and must not exceeding $\arg\min\{a_1, ..., a_n\}$. If all players choose $c_j = a_j$ also the reciprocity rule will fully cooperate with $c_i = a_i$.

In the following we analyze a static version of the game. To account for dynamic aspects we will extend the opportunistic rule in the following way: If a free-riding country wants to benefit from positive contributions of other countries in the future, it has an incentive to prevent these countries from switching to the opportunistic rule. Even if the reciprocity norm is not binding for the opportunistic country, it has self-interest in preserving this norm in other countries. Hence, opportunistic countries may 'imitate' reciprocal behavior by making (small) contributions c^{oi} which solves

$$\min_{c_i \in [0, a_i]} c_i \quad s.t. \quad u_j(s_j, s_{-j}) > 0 \; \forall j \in \{k | f_k = f^r\}.$$

This critical contribution is at least a neccessary contition for the norm-guided players to stay cooperative because this guarantees positive payoffs compared to zero payoff in a pure opportunistic scenario. This kind of behavior is called imitation rule f^{oi} and is a variant of rational opportunistic behavior. All rules have the property that each rule profile $(f_1, ..., f_n)$ implies a unique behavioral equilibrium what makes the analysis comfortable.

4 VOLUNTARY POLLUTION REDUCTION: THE CASE OF THREE COUNTRIES

4.1 Identical countries

Assume that there are $n = 3$ countries which are responsible for globally relevant emissions. The governments of these countries know that a reduction of these emissions is desireable and welfare-improving. For simplicity we normalize the reduction goal to one and assume that each country i can commit itself to reduction contributions which cannot exceed a_i with $\sum_i a_i = 1$. The decision behavior in these countries is characterized by a rule $f_i \in \{f^o, f^r\}$. Since the countries or governments, respectively, interact for a very long time, it can be justiified that behavioral rules are assumened to be Common Knowledge. We have four possible rule profiles:

$$(f^o, f^o, f^o),\ (f^o, f^r, f^r),\ (f^o, f^o, f^r)\ (f^r, f^r, f^r).$$

Obviously (f^o, f^o, f^r) can never be an equilibrium profile because the norm-guided country will have negative payoffs $u_i = (\beta_i - 1)b < 0$ so that switching to the opportunistic rule is always beneficial. Furthermore, with certain parametrizations, also a f^o-player may benefit from switching to f^r. It has to be noted that pure opportunistic behavior (f^o, f^o, f^o) is always an equilibrium rule profile. No country can benefit from unilaterally adopting the reciprocity rule.

However, a remarkable number of cases of voluntary contributions to global environmental policy can empirically be observed. This can be explained by the hypothesis that norm-guided reciprocal behavior is beneficial and that an unilateral switch to free-riding will also harm the switching country itself. Of course the opportunistic country would ceteris paribus have additional payoffs $-(\beta_i - 1)c_i > 0$ but since free-riding reduces the average contribution it induces the norm-guided countries to reduce their efforts as well. To keep analysis simple we first consider the case of three identical countries, i.e. $a_i = 1/3 \forall i$ and $\beta_i = \beta \forall i$. It turns out that in case of $F = \{f^o, f^r\}$ only pure opportunistic or pure reciprocity behavior can be equilibrium profiles:

Proposition: Let $F = \{f^o, f^r\}$ and $a_i = 1/3,\ \beta_i = \beta \forall i$. Then (f^o, f^o, f^o) is the unique equilibrium profile if and only if

$$\beta < \frac{1}{3}\frac{3b+1}{1-b}.$$

Otherwise (f^o, f^o, f^o) and (f^r, f^r, f^r) are both equilibrium profiles.

Proof: Consider the behavioral equilibria induced by (f^r, f^r, f^r), (f^r, f^r, f^o) and (f^r, f^o, f^o) by calculating the fixpoint of the system $c_i = f_i(c_{-i}),\ i = 1, 2, 3$ where f_i is either (2) or (3):

$$\begin{aligned} c_i^r = a_i = \frac{1}{3} &\quad \text{for} \quad (f^r, f^r, f^r), \\ c_i^r = \frac{2b}{3b+1},\ c_j^o = 0 &\quad \text{for} \quad (f^r, f^r, f^o), \\ c_i^r = b,\ c_j^o = 0 &\quad \text{for} \quad (f^r, f^0, f^o), \end{aligned}$$

with the payoffs

$$u_i^{rrr} = \beta - \frac{1}{3} > 0, \quad u_i^{rro} = \frac{2b(2\beta - 1)}{3b+1}, \quad u_i^{orr} = \frac{4b\beta}{3b+1},$$
$$u_i^{roo} = b(\beta - 1) < 0, \quad u_i^{oro} = b\beta > 0.$$

The three upper indices denote the rules of the three players where the first upper index denotes the rule of the actual player. If one country adopts f^o and the second country adopts f^r the third country will benefit from adopting the reciprocity rule if

$$u_i^{rro} \geq u_i^{oro} \qquad \Longleftrightarrow \qquad \beta \geq \frac{2}{3}\frac{1}{1-b} = \beta^*$$

If two countries adopt f^r then the third country benefits from adopting f^r if

$$u_i^{rrr} \geq u_i^{orr} \qquad \Longleftrightarrow \qquad \beta \geq \frac{1}{3}\frac{3b+1}{1-b} = \beta^{**}$$

Since the base rate $b > 0$ cannot exceed $a_i = 1/3$ it follows $\beta^{**} \leq \beta^* \; \forall b$ (see figure 1). If $\beta < \beta^{**}$ the profile (f^r, f^r, f^r) is not an equilibrium because it is beneficial for one country to deviate. But also the resulting configuration (f^r, f^r, f^o) ist not an equilibrium because $\beta < \beta^{**}$ implies $\beta < \beta^*$. Therefore, it is beneficial for one of the remaining f^r-players also to switch to opportunistic rule. It is evident that the resulting profile (f^r, f^o, f^o) is also no equilibrium. Hence, (f^o, f^o, f^o) is the unique equilibrium. For $\beta > \beta^{**}$ it is evident that (f^r, f^r, f^r) is an additional equilibrium profile.

Corollary: If $\beta > \beta^{**}$ holds true the emerging equilibrium profile (f^r, f^r, f^r) can have different 'basins of attraction'. Assume that $\beta > \beta^* > \beta^{**}$. Then with (f^o, f^r, f^r) as well with (f^o, f^r, f^o) it is beneficial for an opportunistic player to switch to f^r. In case of $\beta^* > \beta > \beta^{**}$ in the same rule profiles it is beneficial for one norm-guided player to switch to f^o, and the cooperation will break down. Positive contributions to the public good then require that *all* countries decide according to f^r.

The static analysis provides a very limited view on the behavior of governments. It has been argued that in the long run the behavioral patterns may change and adapt to better performing rules. In a scenario where one or two countries are free-riders it is easy to anticipate that – depending on β_i^*, β_i^{**} – the norm-guided behavior in the

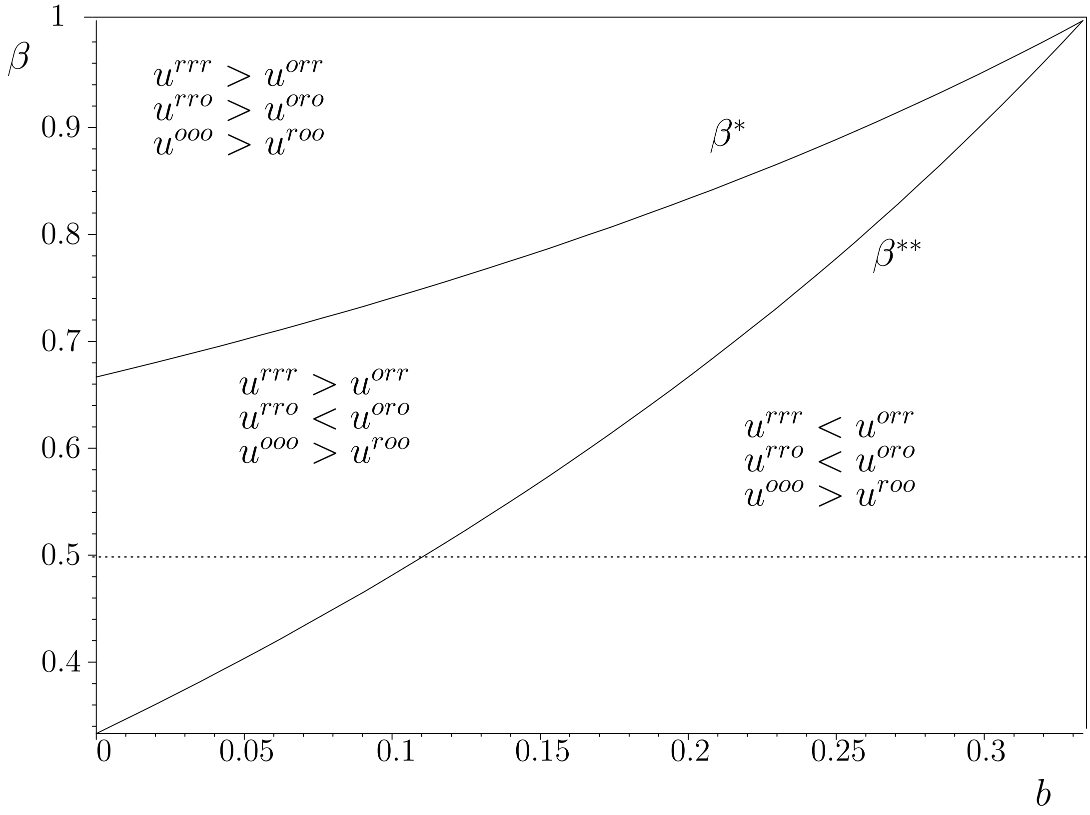

Figure 1: Critical values for β

other countries will perform poorly. There is the danger that the norm 'erodes' and all countries will behave opportunistic in the long run. There may be an incentive for an opportunistic country to 'simulate' reciprocal behavior in order to sway the norm-guided countries to keep their norms. The consideration is that the opportunistic country waives a part of its large payoffs from free riding by making little contributions to the public good. This will at least be compensated by positive payoffs in the future (instead of running into a complete non-cooerative solution with zero payoffs). Even if the country imitates reciprocal behavior, it is still rational because it maximizes discounted payoffs. As discussed above, we refer to this kind of behavior as rule f^{oi}.

Assume a scenario (f^r, f^r, f^{oi}). The opportunistic player may have an incentive to assure that the norm-guided countries have a positive payoff in the long run. Basic algebraic calculations show that the critical contribution of the imitating country is

$$c^{oi} = \min\left(\max\left(0, \frac{2b(1-2\beta)}{(3b+3\beta-3b\beta-1)}\right), a_i\right).$$

The critical contribution is positive if $\beta < 1/2$ holds true (see the dotted line in figure 1). In case of $1/2 < \beta < \beta^{**}$ imitation is not beneficial in this profile. Inserting c^{oi} into the behavioral equilibrium yields the corresponding contributions of the norm-guided countries:

$$c^r = \frac{2b\beta}{(3b+3\beta-3b\beta-1)} \geq c^{oi}$$

Similar considerations hold true for the case of (f^r, f^{oi}, f^{oi}). In general, it is never beneficial for a country to be the unique norm-guided player. But the opportunistic players can sway it to keep the norm by making some (small) contributions. Since each opportuinistic agent will benefit from the imitating behavior of the other country, it is a coordination problem how the burden of neccessary critical contribution should be allocated to the opportunistic players. If one opportunist reduces his contribution unilaterally, the other opportunist has an incentive to increase his contribution in order to assure the critical total contribution level. Hence, there will be a continuum of solutions where the critical total contribution

$$c^{OI} = \frac{2b(1-\beta)}{(3b+3\beta-3b\beta-1)} > c^{oi}$$

is somehow allocated to the two opportunistic countries. For each feasible (b, β)-parametrization $c^{OI} \geq 0$ holds true. These results, based on some dynamic considerations, show that a variety of reciprocal and opportunistic (imitating) behavior can be justified as equilibrium profiles. The possible equilibrium profiles (except for (f^o, f^o, f^o)) are depicted in figure 2.

4.2 Country-specific parametrizations

We assume that the parameters β_i are different, e.g. because the countries are affected by the external effect in different ways or have different opportunity costs of pollution reduction. Then we have specific critical values β_i^* and β_i^{**}. In case of $\beta_1 > \beta_1^*, \beta_2 > \beta_2^*, \beta_3 < \beta_3^*$ there is an additional equilibrium profile (f^r, f^r, f^o). Reciprocal and opportunistic behavior co-exist in this case. If the model is generalized to n

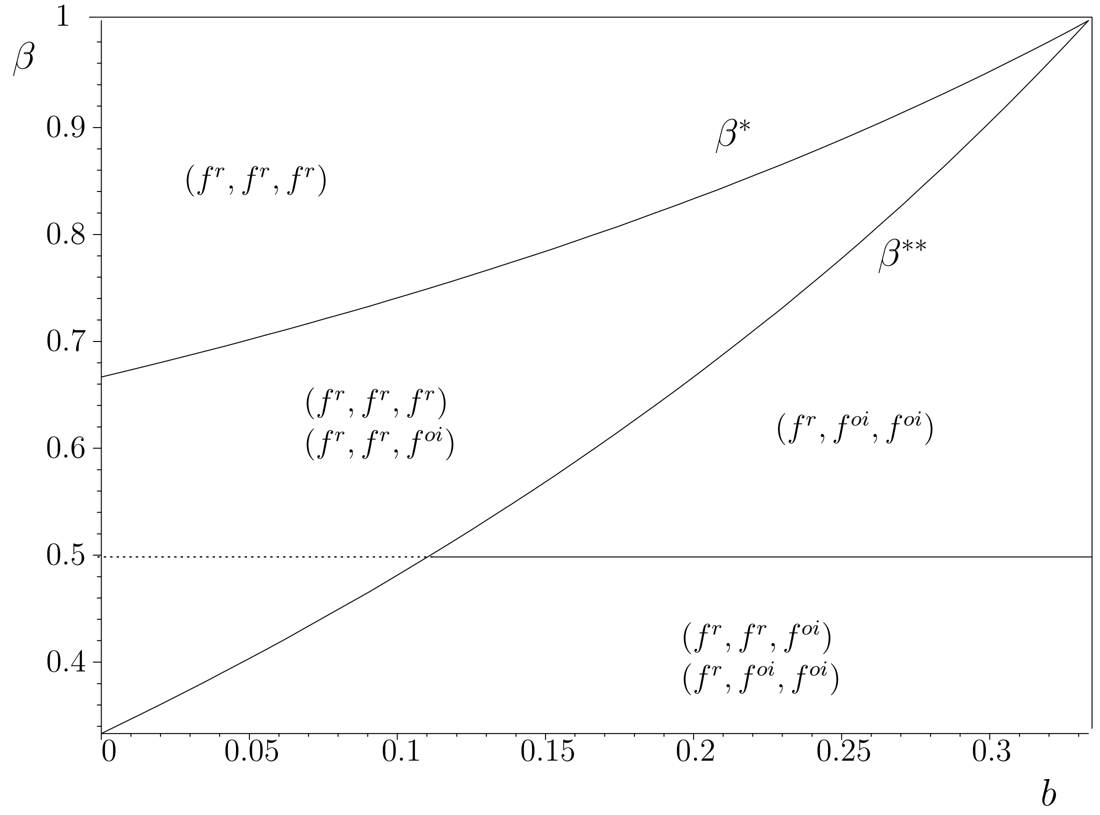

Figure 2: Additional equilibrium regimes

countries it could be expected that there exist multiple equilibrium profiles with different proportions of free-riding and cooperative behavior, depending on the distribution of β_i.

A further variation concerns the magnitude of the countries, measured by their environmental impact a_i. To incorporate such magnitude differences into the model in a simple way we assume that there are two identical small and one big country: $a_1 = a_2 = a,\ a_3 = 1 - 2a$ (without loss of generality it is assumened that the big country has the index 3). The parameter a is then a further degree of freedom in the analysis. It can be shown that the qualitative results of the former section are not much affected by this modification. It turns out that for the big country it is more likely to be an opportunist as for a small country. This is plausible because the big country has only little benefits from the contributions of small countries while the payoff decreases with each reduced unit of own emissions. On the other hand the small countries have large benefits from the efforts of the big player. Assume that both small countries follow the reciprocity rule f^r. From computation of the behavioral equilibrium payoffs we obtain the critical β-value for the big country

$$\beta_3^{**} = \frac{(1-2a)(b+a)}{b+a-4ba} \geq \beta^{**}$$

which is larger than the according critical value in case of three countries of the same size ($a = 1/3$). It is not surprising that the critical value β_3^{**} negatively depends on a: The larger the inequality between small and big countries is, the higher the marginal returns on contribution have to be in order to motivate the big country for cooperation. The same result is obtained for the critical β-value in case of one cooperative and one free-riding small country:

$$\beta_3^{*} = \frac{2(1-2a)}{2-3a-b} \geq \beta^{*}$$

Since $\beta_3^* > \beta_3^{**}$ holds true, it is more likely to run into a complete free-rider situation, the larger the inequality between the country sizes is. In figure 3 both critical β-values are plotted for the case $a = 1/4$ (dotted lines for equally sized countries).

If the big country does not cooperate it is very likely that also the norm-guided countries will switch to f^o in the long run. This would also have a negative impact on the big country. Hence, there may be an incentive to imitate reciprocal behavior by making small pollution reduction efforts. The critical value to sway the small countries to behave cooperative is

$$c_3^{oi} = \min\left(\max\left(0, \frac{(1-2a)(2a-3a\beta+b\beta)b}{(ba-a^2-4ab\beta+b\beta+a\beta)}\right), a\right).$$

This implies that the larger the size difference is, the lower is the critical contribution of the opportunist ($\partial c_3^{oi}/\partial a > 0$). But even if the big player contributes nothing, the small countries will adopt f^r if

$$\beta_i > \frac{2a}{3a-b}.$$

Even if this condition does not hold true, one small country may motivate another small country to keep up the reciprocity norm by making ‘imitating’ contributions

$$c_i^{oi} = \min\left(\max\left(0, \frac{2ab(\beta-1)}{a-b-(b-3a)\beta}\right), a\right).$$

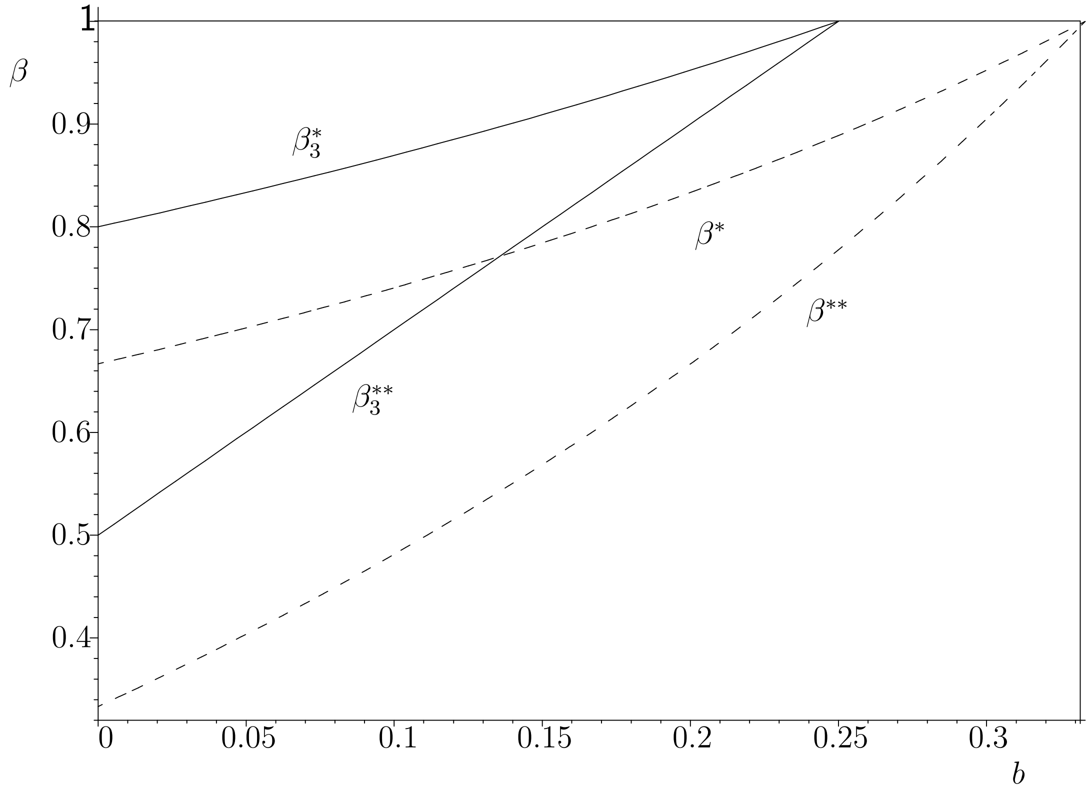

Figure 3: Critical values for β in case of a big country

These are possible explanations why small countries commit themselves to substantial environmental policy while the big country behaves as a free rider – like it is the case of US policy of non ratifying the Kyoto protocol (cf. Hovi/Skodvin/Andresen (2003) for further analysis of the motives of small countries).

5 Conclusion

The analysis provides the following results:

- Norm-guided reciprocal behavior as well as opportunistic free riding can be a part of equilibrium profiles and are hence justifiable as reasonable behavioral patterns. This means that substantial contributions to a global environmental policy are possible. The problem of free riding in a public good game can partially be overcome even without supranational institutions which are able to sanction governments. This is in sharp contrast to classic game-theoretic analysis which is based on pure rational behavior.

- The distribution of diffferent behavioral rules and hence the distribution of pollution reduction efforts depends on a_i and β_i. Cooperation is more likely if the marginal returns on contributions β_i are high.
- Large inequalities in country sizes (different a_i) make voluntary contributions more unlikely. The parameter regions wehere big countries benefit from free riding are larger than in case of equally sized countries.
- In all cases the danger of running into a complete non-cooperative situation (f^o, f^o, f^o) in the long run can be ward off when the opportunistic countries 'imitate' reciprocal behavior by making small pollution reduction efforts.

What can countries do in order to motivate other countries to behave reciprocally or at least to imitate reciprocal behavior? First, it may be possible that the marginal return on contribution can be increased by *side-payments* of the cooperative countries. This presupposes that for the opportunistic country the side-payments overcompensate the negative payoff effect of own contributions, and that the payments are smaller than the additional benefits of the norm-guided countries.

Another, more simple, possibility is to *change the base rate of cooperation b*. Consider (f^r, f^r, f^o). The critical value β^{**} in case of identical countries (see figure 1) implies that for aech value of β there exists a sufficiently low value for b so that the opportunistic player benefits from switching to f^r. In case of differently sized countries, instead, there is always an interval of sufficiently low β-values so that this mechanism unfortunately does not work (see figure 3). A decrease in the base rate b will sway the big country to adopt f^r only in case of hgh β_3-values.

If there is no possibility to motivate a country to adopt f^r it is possible to increase their 'imitating' contributions (if they imitate at all). The expressions c^{oi}, c^{OI}, c_3^{oi} show that the imitating contributions and hence the total wealth are positively related with b. In this case norm-guided countries would benefit from increasing the base rate b. Since in reality the values of β_i are very uncertain and may also depend on private information about subjective values, an increase of the base rate is very risky, however, because this also increases β_i^*, β_i^{**} and may induce opportunism.

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