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Inducing Environmental Co-operation by the Design of Emission Permits

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Summary

Strategies of international risk management, as the implementation of tradable emission permits, feed back to the incentive structure of a treaty, like the Kyoto Protocol. Discussing the Kyoto Protocol the question was: Should there be any restrictions on the trading of emission permits or not?
With the help of a simple two country model it is shown that the enforcement of environmental treaties critically depends on the type and the intensity of national risk preferences. Assuming that the 'global alliance of risk' decreases with each co-operative contribution, risk aversion is a prerequisite for enhancing the chances of global risk management. It is moreover the national intensity of risk aversion that determines whether trade should be restricted or not. In some cases the chances of international coalition formation are expected to improve only if less risk averse countries dictate the rules of the game, here: the design of the permit regime.

Keywords: Environmental co-operation, country-specific risk preferences, game theoretic approach, typology of co-operative behaviour, design of emission permits

JEL: D7, D8, F1, H4, Q2

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Inducing Environmental Co-operation by the Design of Emission Permits*

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1. Introduction

The underprovision of global public goods is a challenge to national and international management. One of the most famous examples is the control of global environmental risks. Since there are no supranational institutions to effectively provide and protect a sufficient (not to speak of an optimal) level of global environmental quality, managing the global commons calls for joint measures of the nations, taken voluntarily. In principle, there is an international consensus with regard to this issue, as confirmed by the Earth Summit held in Rio de Janeiro 1992 and many subsequent international conferences. However real world experience reveals that a compromise is hard to reach and to maintain. For example, prepairing the Kyoto Protocol took about 10 years. Although ratification is expected yet, the risk of non-compliance (until the budget period 2008-2012) remains. These problems do not come as a big surprise to the analysing economist since they are just other manifestations of the general dilemma in individual and collective rationality with regard to the supply of public goods: Each country benefits from the provision of the public good but does best when enjoying the services provided by others as a free rider. In terms of game theory, this dismal incentive structure is modelled by dilemma games (as the Prisoners Dilemma- or the Chicken game)[1].

Given that a Prisoners' Dilemma is at work, nations are expected to hold on to the status quo (the business as usual) which is unfavourable for each of them compared to mutual emission reduction (global co-operation). Given the Chicken, at least a subgroup of nations is willing to

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1 For an introduction into game theory see e.g. Luce/Raiffa (1989); for a modern version e.g. Eichberger (1998). For the games addressed in the paper at hand also see Oye (1986), Snidal (1988).

provide some of the public good unilaterally. However global risk management e.g., performed by the control of greenhouse gases, (at least in the long run) calls for co-operative measures taken by a broad range of countries (as is the outcome of a coordination game like the Stag Hunt).[2] Therefore enlarging co-operation is as important as initiating it. In the paper at hand it is shown that which type of game is played – a dilemma game or a coordination game – will crucially depend on the design of policy instruments, here: the design of emission permits.

This issue was already dealt with in a paper by Endres/Ohl (2001). There the discussion (among others) concentrates on the controversy on the permit design for the trade of greenhouse gases at COP 4 in Kyoto 1997. In Kyoto the question remained unanswered whether the trade of emission permits should be bounded by trade restrictions or not. Now, since the Marrakech agreements as of November 2001, we know that a ratification of the Kyoto protocol called for a regime[3] allowing the trade of the whole amount of emission rights. The paper at hand therefore first recalls the results of the paper by Endres/Ohl (2001) and then evaluates them in the new light of the Marrakech results.

The paper proceeds as follows:
The subsequent *part two* of the paper introduces the model. *Part three* delivers the suppositions (in terms of two threshold values) for international co-operation to take place which is a necessary condition for the establishment of a regime on tradable emission rights. *Part four* shows how the design of policy instruments, here: the design of emission permits, feeds back to the chances of international coalitions formation (the incentive structure of the game nations are expected to play). *Part five* summarizes the main findings and discusses the implications for global risk management.

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2 That the efforts of emission reductions taken by a subgroup of countries may be counterbalanced by free riders (non co-operating countries) was already pointed out in the literature by Hoel (1991).

3 See e.g. Haggard/Simmons (1987), Neumayer (2001) and the literature cited there for an introduction into the work of regime theory and the definition of the expression used above.

2. The Model

The focus is on two nations, the home country and the foreign country. Each country is interpreted as one group of countries having a common interest. In the context of climate negotiations think of the formation of the „Umbrella group“ and the „Bubble group“ in Kyoto 1997 (see e.g. Michaelowa/Koch 1999). Each country is able to choose between co-operation and defection. In the case of co-operation the country under consideration takes part in an international treaty, here: aiming at the control of greenhouse gases. In the case of defection the country will not join the agreement i.e., it holds on to the business as usual where emissions are expected to be higher than in the case of joining the agreement. The consequences of choosing either of these options are uncertain. That is the benefits and costs of emission control are not known with certainty to the governments of the countries. We thus have to deal with a national welfare distribution which here is characterized by its means μ and its standard deviation σ.[4]

2.1. The prisoners' dilemma

In general, no sovereign country can be forced to implement costly cooperative measures. Therefore the risk of free riding remains. As is widely documented in the literature, that is the reason why the condition for stable coalition formation is not easily fulfilled even if all individual countries would benefit from signing and enforcing an international convention (problem of self-enforcement e.g., Barrett 1994, 1997, 1999, Endres 1997a, b).[5] Hence to characterise the interdependencies of nations aiming at the control of greenhouse gases, the Prisoners' Dilemma is a relevant game. According to this type of game expected welfare of the nations reads as follows:

(1) $\mu_{DC} > \mu_{CC} > \mu_{DD} > \mu_{CD} > 0$

The first entry in the subscript indicates the risky option chosen by the home country; the second entry indicates the risky option as chosen by the foreign country. Ranking (1) states

[4] For different measures of risk in the context of environmental change e.g. see Brachinger/Weber (1997).

[5] Of course, there are international institutions aiming to enforce these agreements. However, noncompliance seems to be the rule, rather than the exception. E.g. see, Brown-Weiss/Jacobson (1997), Finus (1999), Keohane (1995), Michaelowa/Koch (1999), Sand (1992).

that from a home country's point of view expected national welfare is highest when choosing to defect: $\mu_{DC} > \mu_{CC}$ and $\mu_{DD} > \mu_{CD}$.

Thus challenged by expected national welfare maximization only, nations are kept in the status quo which, compared to mutual co-operation, is unfavorable for all of them ($\mu_{CC} > \mu_{DD}$). However in reality nations are not necessarily willing to pay the (ecological) price for enhancing the national welfare situation in terms of expected welfare μ. Especially in cases where nations are of the risk seeking- or the risk averse type countries are also concerned about the development of additional risk measures, as the sway of the welfare distributions σ.

2.2. The global alliance of risk

The sway of the outcomes σ is determined by economic as well as scientific uncertainties. Economic uncertainty is given with respect to abatement cost as well as damages (e.g., Stavins 1996, Xepapadeas 1997, Hanley/Spash 1993). However, regarding global environmental change uncertainty of environmental damage due to scientific lacks of knowledge seems to be the most important factor. Scientific uncertainty, here regarding climate change, exists with respect to the role of the oceans and the natural sinks absorbing greenhouse gases. The harm done to the environment by each emission unit is therefore difficult to assess. Besides, there is exogenous uncertainty, e.g. regarding the activity of sunspots or the position of earth to sun and their relations to climate change. Subsequently, anthropogenic and natural climate variations and their impact on the level of environmental damage are hard to distinguish.[6] But opposed to exogenous uncertainty, anthropogenic effects can be reduced. The simple principle holds: Each pollution unit abated or not emitted in the first place reduces man-made environmental effects (endogenous environmental risk; Chichilnisky/Heal 1998). Consequently, put it the other way round, national cutbacks in emissions are able to cause variations in the level of damage as well as in the level of damage probability. Thus, not only the means (μ), but also the spread parameters (σ) are sensitive to the choice of a strategic option (here: C or D). Unfortunately, to date, it is unclear whether the means and the standard deviation are positive, negative or not at all correlated.

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[6] For further details regarding scientific uncertainties see e. g. Houghton et al. (1996).

However if first, the sway of the welfare distribution is a functional relation of the emission behaviour of mankind and if second, the level of emissions is uncertain because of an unknown development of economic variables (like the GDP) then, agreeing on emissions control (a certain target level), the sway of the welfare distributions as a consequence of economic-(GDP-)uncertainties is counterbalanced by environmental policy. Thus a plausible hypotheses on the development of the standard deviation (σ) reads as follows:[7]

(2) $\sigma_{DD} > \sigma_{CD} = \sigma_{DC} > \sigma_{CC} > 0$

The „global alliance of risk" as characterised by (2) states that independent from which nation is acting each cooperative contribution reduces the (anthropogenically caused) spread of the welfare distribution. That is: Cutting back emissions, the alliance of risk (2) results in a shift of the home country's as well as that of the foreign country's spread parameter (σ). The lowest standard deviation is reached when both countries cooperate simultaneously. Moreover, if nations are assumed to cut back emissions by the same pre-specified amount, equality between σ_{CD} and σ_{DC} holds.

With the means μ and the spread parameters σ the focus is on the two main parameters assessed by the natural sciences in order to define the indicators of global environmental change. The most famous example is the assessment of the mean temperature and the sway of its daily amplitude. Moreover think of the measurement of the average amount of rain per incidence of rainfall and the calculation of the standard deviation in order to catch a change in the extremes, which is in flash floods on the one hand and in draughts on the other hand. These data provide the scientific input for the political decision maker. Therefore it is very suggestive that nations link the developments of the means and the spreads of the different indicators to the national welfare situation and thus (at least implicitly) decide upon co-operation and defection in terms of μ and σ.[8]

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[7] For further details on the correlation of μ and σ as well as an alternative modelling of the "global alliance of risk" see Endres/Ohl (2001).

[8] That nations indeed inhibit some kind of spread preferences is also revealed by the definition of the suppositions for the enforcement of the European monetary union. Moreover in societal discussions the stability e.g. of money, of income, of prices as well as the climate stability play a crucial role.

2.3. The risk-welfare function

In order to judge the risky options under consideration (here: C and D) by the country-specific risk attitudes we have to select one decision rule out of the variety of decision criteria provided in the literature.[9] In the paper at hand – as in traditional environmental economic analysis - it is assumed that environmental damage continuously varies with the level of emissions (e.g., Endres 2000, Kolstad 2000). If risk is of this conventional type the von Neumann-Morgenstern approach (von Neumann/Morgenstern 1953) seems to be appropriate to judge the national risk welfare situation.[10]

The expected utility approach of von Neumann and Morgenstern is the most convincing one from a normative point of view. Taking a descriptive point of view, however, this approach is regularly criticised (e.g. see Allais 1953, Kahneman/Tversky 1979, 1981, Machina 1997). On the other hand Currim/Sarin (1989) point out that the von Neumann-Morgenstern approach is able to deliver useful insights from a descriptive point of view as well; i.e. in cases where the focus is on a conventional setting as in the paper at hand.[11] However the von Neumann-Morgenstern approach has the disadvantage of not explicitly dealing with the stochastic terms of the model. Thus, in the paper at hand, the focus is on the well established μ-σ-criteria which follow the axioms of the expected utility approach by explicitly taking the stochastic parameters into account (e.g. see Huang/Litzenberger 1988; Sinn 1990). Choosing a linear version of these criteria we have risk utility as given by:[12]

(3) $\phi = \mu - \alpha\sigma$ with

(4) $\partial\phi/\partial\mu > 0 \; \forall\alpha$ and

(5a) $\partial\phi/\partial\sigma < 0$ for risk aversion ($\alpha > 0$)

(5b) $\partial\phi/\partial\sigma = 0$ for risk-neutrality ($\alpha = 0$)

(5c) $\partial\phi/\partial\sigma > 0$ for risk-loving ($\alpha < 0$)

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9 For an overview e.g. see Sinn (1989).

10 An alternative view is needed if the focus is explicitly on the "catastrophic" type of risk. This type of risk is not adequately modelled using the expected utility framework. See e.g. Chichilnisky (2000). However, considering the time horizon of the Kyoto Protocol (the targets have to be reached within the budget period 2008-2012) the catastrophic type of risk does not play the pre-dominant role. For further details on this point see Endres/Ohl (2001) and the literature cited there.

11 For new developments in descriptive theory of choice under risk see Starmer (2000).

12 The choice of a linear utility function is not crucial for the results derived, here. They are also displayed by a quadratic utility criterion treating the risky options as inferior goods.

According to (3) national welfare in terms of national risk utility is given by the preference parameter ϕ. The value of ϕ is determined by the level of the mean μ which records nationally expected welfare and the standard deviation σ being weighed by a national risk discount (α). With it, decision function (3) reflects the impact of the stochastic terms (μ and σ) on the national welfare situation. (4) states that independent of the country-specific risk attitude, the preference value increases if the mean rises. However, depending on the national attitude towards risk, ϕ adapts to changes of σ: For risk-averse countries ϕ decreases if σ rises (5a); given risk-neutrality σ does not alter the preference value (5b) and, in risk-loving nations ϕ and σ develop in the same direction (5c). The higher ϕ the higher is the national welfare measured in terms of risk-utility.

3. The co-operative power of national risk preferences

Nationally, environmental measures can be introduced and enforced by the government. In a supra-national context, however, environmental policy must be negotiated among sovereign nations. Thus, to be reliable, emission reduction must be rewarding for each participating country i.e., the international agreement on this reduction must be incentive compatible and self-enforcing. Therefore, before we analyse which design of a trade regime of emission permits is the most co-operative one, we have to derive a profile of conditions indicating in which cases nations are expected to join a treaty (here: in order to introduce the control of greenhouse gases).

An impulse for taking over protective measures of the environment arises if at least indifference between the choice of defection and co-operation holds. Based on the model as specified by (1), (2) and (3) as well as on the foreign country's choice, that is when the following conditions hold:

1. The foreign country defects:

$$\phi(CD)=\phi(DD) \Rightarrow (\mu_{DD}-\mu_{CD})/(\sigma_{DD}-\sigma_{CD}) \equiv \alpha_{C}^{min}>0 \qquad \text{(I)}$$

2. The foreign country co-operates:

$$\phi(CC)=\phi(DC) \Rightarrow (\mu_{DC}-\mu_{CC})/(\sigma_{DC}-\sigma_{CC}) \equiv \alpha_{CC}^{min}>0 \qquad \text{(II)}$$

Conditions (I) and (II) define two threshold values (α_{Cmin} and α_{CCmin}). Both thresholds are defined by the stochastic parameters, μ and σ. The threshold value α_{Cmin} names the critical level of risk attitude which must be passed by the actual risk preferences (α) in order to stimulate *unilateral* co-operation (incentive compatibility: $\alpha \geq \alpha_{Cmin}$). The threshold value α_{CCmin} separates stable from unstable co-operation (condition of self-enforcement: $\alpha \geq \alpha_{CCmin}$). If the actual α passes α_{CCmin}, *bilateral* co-operation takes place.

Given the orders of μ and σ as of (2) and (3) both threshold values are positive (α_C^{min}, $\alpha_{CC}^{min}>0$). Hence it is only risk aversion ($\alpha>0$) that fosters measures of global risk reduction. The threshold values determine the critical intensity of risk aversion for which nations are indifferent between the choice of defection and co-operation. Although α_{CCmin} delivers the necessary condition for making *both* countries co-operate and α_{Cmin} focuses on the suppositions for co-operation of *one* country only, it can be shown that α_{CCmin} is not necessarily higher than α_{Cmin}.[13] Thus enhancing the possibility of international co-operation does not necessarily claim for a higher threshold value.

Table 1 below points out that dependent on he relation of α_C^{min}, α_{CC}^{min} and the actual intensity of risk aversion different types of games evolve:

[13] The case $\alpha_C^{min}>\alpha_{CC}^{min}$ e.g. holds when $(\mu_{DD}-\mu_{CD})= (\mu_{DC}-\mu_{CC})$ and $(\sigma_{DD}-\sigma_{CD}) < (\sigma_{DC}-\sigma_{CC})$. That is when the control of the global pollutant comes up with a synergism regarding the spread of the welfare distributions. Then, the decrease in the spread is higher in the case of bilateral co-operation than in the case of unilateral.

Type of game	Incentive structure	Relation of the threshold values (α_C^{min} and α_{CC}^{min}) and the national risk attitude (α)
Prisoners' Dilemma	$\phi(DC) > \phi(CC) > \phi(DD) > \phi(CD)$	$\alpha < \alpha_C^{min}; \alpha_{CC}^{min}$
Chicken	$\phi(DC) > \phi(CC) > \phi(CD) > \phi(DD)$	$\alpha_C^{min} < \alpha < \alpha_{CC}^{min}$
Stag Hunt	$\phi(CC) > \phi(DC) > \phi(DD) > \phi(CD)$	$\alpha_C^{min} > \alpha > \alpha_{CC}^{min}$
No Conflict	$\phi(CC) > \phi(DC) > \phi(CD) > \phi(DD)$	$\alpha_C^{min}; \alpha_{CC}^{min} < \alpha$

Table 1: A typology of cooperative behaviour

The threshold values in relation to the actual intensity of risk aversion co-determine whether an incentive to cooperate exists and if so whether this incentive is stable. According to table 1 above we see:

In cases where the national risk attitude α is lower than both of the threshold values a Prisoners' Dilemma is played ($\alpha < \alpha_C^{min}, \alpha_{CC}^{min}$). However as soon as α passes one of the threshold values a game of higher co-operation possibility becomes feasible. Whether it is a coordination- or a dilemma game critically depends on the relation of α_C^{min} and α_{CC}^{min}. In cases where $\alpha_C^{min} < \alpha_{CC}^{min}$ holds and the actual intensity of risk aversion lies in-between, nations face the Chicken game ($\alpha_C^{min} < \alpha < \alpha_{CC}^{min}$). If, however, $\alpha_C^{min} > \alpha_{CC}^{min}$ holds, nations play the game of Stag Hunt ($\alpha_C^{min} > \alpha > \alpha_{CC}^{min}$). Thus (!) enforcing an agreement is not necessarily harder than initiating it. Moreover, in cases where α exceeds both of the threshold values ($\alpha_C^{min}, \alpha_{CC}^{min} < \alpha$) even a No Conflict game is able to arise.

All in all, the results given in Table 1 explain why – even in cases where expected welfare of the nations follows the incentive structure of the Prisoners' dilemma - some of the countries take over binding commitments while others don't. Given the stochastic parameters, the country-specific risk attitude determines whether co-operation is feasible or not.

So, as Binmore (1991) puts it: World as it is usually faces *good* and *bad* equilibria at the same time. Therefore the problem is how to settle down on a good one rather than a bad one.

In Reality in general the country-specific risk attitudes as well as their intensities (at least in the short run) have to be taken for given. Nevertheless nations have the chance to select among the different types of games by measures of risk management. Below, it is shown how the design of environmental policy, here: the design of emission permits, is able to alter the game nations are expected to play (and with it the quality of expected equilibrium).

4. Defining the game by measures of risk management

In a national context the advantages and disadvantages of environmental policy (its instruments and technologies) have been sufficiently discussed in the literature according to the different criteria. Economists have given close attention to the efficiency criterion indicating whether a given instrument is able to attain a pre-determined target level (in terms of emissions or ambient air-, water-, soil quality) with minimal cost. Additionally, the focus was on the criterion of ecological accuracy pointing out the degree of exactness with which the instrument is able to reach the target.[14] However, to date, it is unclear how to integrate the instruments' pros and cons with respect to these different criteria into an overall assessment. If one instrument is more efficient but less accurate than the other, one can usually not say which one the best to choose.[15] Additionally, the traditional criteria are not readily applied to evaluate the power of alternative instruments to initiate and enforce internationally coordinated measures of global risk reduction; that is: according to the abilities of instruments to minimize the threshold values.[16]

In the paper at hand it is shown that which policy design is the most effective one to fight global environmental change (in terms of international co-operation) will critically depend on the national risk attitudes as well as the policy designs' performance under the traditional criteria.

Focusing on anthropogenic caused risks nations are able to alter the level of damage as well as damage probability. Consequently given the national risk attitude, μ and σ are the main

14 Aspects of ecological accuracy are also dealt with in terms of output controllability (Weitzman 1974) or quantity distortions (Baumol/Oates 1988).

15 In fact, there are analyses dealing with this subject (e.g, Weitzman 1974, Yohe 1977, Baumol/Oates 1988, Hoel/Karp 1998). However, these studies usually assume ex ante efficiency for each type of instrument and moreover neglect strategic interdependencies.

16 A first step in this direction is taken by Endres/Ohl (2000) analysing the co-operative push of taxes and quotas.

policy variables of the model. These parameters determine the threshold values, α_C^{min} and α_{CC}^{min}. Since μ and σ depend upon the national damage assessment, the definition of the target as well as on the choice of environmental technology and policy instruments, a skilful management design is able to alter the shape of the national welfare distributions and consequently is able to move both boundaries.

Regarding the Kyoto protocol the target level for example does not focus on the control of the most prominent greenhouse gas, CO_2, only. Instead the Kyoto Protocol explicitly allows for a reduction of the six major greenhouse gases alternatively (these are CO_2, CH_4, N_2O, HFCs, PFCs and SF_6). Switching from the control of one type of pollutant only to the control of a basket of pollutants (here: causing the same type of risk), affects the cost and the benefits of signing a treaty and thus the stochastic terms of the model.[17] The same is true for instruments and technologies differing in efficiency and accuracy (as shown by Endres/Ohl 2000, 2002).

Below, it is shown that which type of policy design is most suitable to enhance the chances of international coalition formation depends on the countries' intensity of national risk aversion on the one hand and on its pros and cons in terms of efficiency and accuracy on the other hand.

3.1. The issue of Efficiency

Considering the reduction of anthropogenic caused risk (at least in theory), risk management is able to produce the whole range of μ-σ combinations in-between the axes of the μ-σ-diagram as given by figure 1, below:[18]

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[17] See Ohl (2002) on how the definition of the target is able to affect the international possibility of co-operation and on how the definition of the target is able to qualify nations as environmental friendly or not.

[18] However usually only a certain range of μ-σ combinations has to be judged. Dealing with the conventional type of risk, politicians (societies) e.g. do not claim for a risk reduction to zero. For further details on this point e.g. see WBGU (2000).

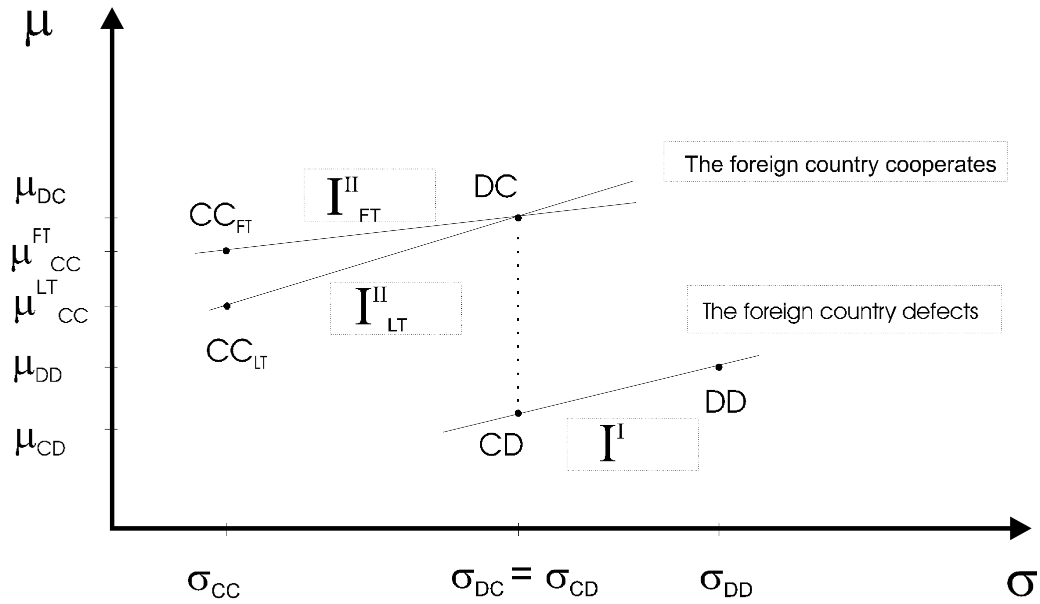

Figure1: Designing an international environmental treaty. Case 1: $\alpha_{CCFT}^{min} < \alpha_{C}^{min} < \alpha_{CCLT}^{min}$

The orders of μ and σ as of (2) and (3) are displayed at the ordinate and the abscissa of figure 1 above.[19] The slopes of the straight lines represent the values of α_C^{min} and α_{CC}^{min}, respectively. Each curvature is the location of different μ-σ-combinations leading to the same demands on the national risk attitude α given the strategy choice of the foreign country. Consequently, we can speak of I^I and I^{II} as of Iso-requirement-curves of co-operation. Each μ-σ-tuple highlights the impact of environmental policy choice on the national welfare distribution. The status quo for example is displayed by DD which refers to a business-as-usual-scenario where no internationally coordinated measures take place.

Considering an international quota regime to limit greenhouse gases, the question in Kyoto 1997 was whether the trade of emission permits should be restricted or not. The Umbrella group with the US as the leading country preferred a free trade of the whole amount of emission rights. On the other hand the Bubble group, leaded by Germany, insisted on a buyers or a sellers cap limiting trade to a certain percentage of the assigned amounts.[20]

From an economic point of view it is well known that trading of emission permits is most effective (in terms of efficiency) if trade is unbounded by a cap. Thus if we call μ^{FT}_{CC} the

[19] The subscripts LT and FT, used in figure 1, will be introduced later in this section.
[20] On this controversy also see e.g. Metz et al. (2001), Oberthür/Ott (1999).

level of expected welfare in the case of free trade (FT) and μ^{LT}_{CC} the level of expected welfare in case of limited trade (LT) we have:

(6) $\mu^{FT}_{CC}>\mu^{LT}_{CC}$

The policy-specific differences in the levels of the means as given by (6) affect the slope of the CC-DC-curve; i.e. the threshold value α_{CC}^{min}. In the case of free trade the threshold is lower than in case of limited trade ($\mu_{DC}-\mu^{FT}_{CC} < \mu_{DC}-\mu^{LT}_{CC} \Rightarrow \alpha_{CCFT}^{min}<\alpha_{CCLT}^{min}$). Hence, all else being equal, the LT-curve is steeper than the FT-curve.[21] Thus we may have the case of figure 1 where $\alpha_{CCFT}^{min}<\alpha_{C}^{min}<\alpha_{CCLT}^{min}$ holds (case 1).

Now focus on a nation which is just indifferent between the choice of defection and the choice of unilateral co-operation. Call this country the *indifferent* nation. For this country the intensity of risk aversion α is close to α_{C}^{min}.[22] Consequently, given case 1, we focus on a nation for which free trade is qualified by a higher cooperative push than trade restrictions ($\alpha_{CCFT}^{min}<\alpha_{C}^{min}\cong\alpha<\alpha_{CCLT}^{min}$). In terms of game theory, the indifferent country plays the No Conflict game in the FT-case and the Chicken in the LT-case.
Hence a quota regime supporting free trade induces stable bilateral co-operation whereas a regime with barriers of trade fails to do this job.

However, regarding the implementation of the Kyoto protocol trade restrictions are expected to have some impact on the emission of greenhouse gases. The reason is that the assigned amounts mainly of the Russian Federation and the Ukraine (as given by the zero reduction targets for these countries) cause the problem of „*hot air*“.[23] In the case of trade restrictions it should become impossible to sell or buy the whole amount of „hot air“. Hence global emissions are expected to be lower in the case of trade restrictions than in the case of free

[21] Notice that the CD-DD-curve is not altered by the design of the trade regime. In a two-country-model trade restrictions only matter in the case of bilateral co-operation. In the case of unilateral emission reduction trading of the amounts avoided among countries does not happen anyway (disregarding the possibility of trading among each group of countries for complexity reduction).

[22] In this case the steepness of the risk utility functions of the indifferent country equals that of the Iso-requirement curve I^{I}.

[23] The term „hot air“ stands for emission rights that are allowed by the Kyoto protocol but will not be called on because of declining economic (and hence emission) growth in some of the eastern European countries. Herold (1998) e.g. calculated that „hot air“ could affect the global emission level of greenhouse gases by an amount of 516-650 mio. tons (only CO_2) during the first budget period (2008-2012). For the problem of „hot air“ also see Böhringer (2001), Böhringer/Löschel (2001), Michaelowa/Koch (1999).

trade. Thus, although the national target levels are fixed by the Kyoto Protocol, the design of the trade regime affects the emission of greenhouse gases. Therefore, having to cope with "hot air", it is not only the means that vary but also the standard deviations (as a function of the global emission level).

3.2. The issue of accuracy

In figure 2, below (case 2), it is assumed that free trade still improves expected welfare of the nations (i.e., efficiency gains from free trade outweigh savings from damage reduction that origin from trade restrictions freezing the amount of tradable „hot air"). That is $\mu^{FT}_{CC} > \mu^{LT}_{CC}$ as given by (6) holds. However, additional to case 1 (shown in figure 1, above), the expected difference in the global emission level now causes a further effect on the standard deviation σ_{CC} as given by:

(7) $\sigma^{FT}_{CC} > \sigma^{LT}_{CC}$

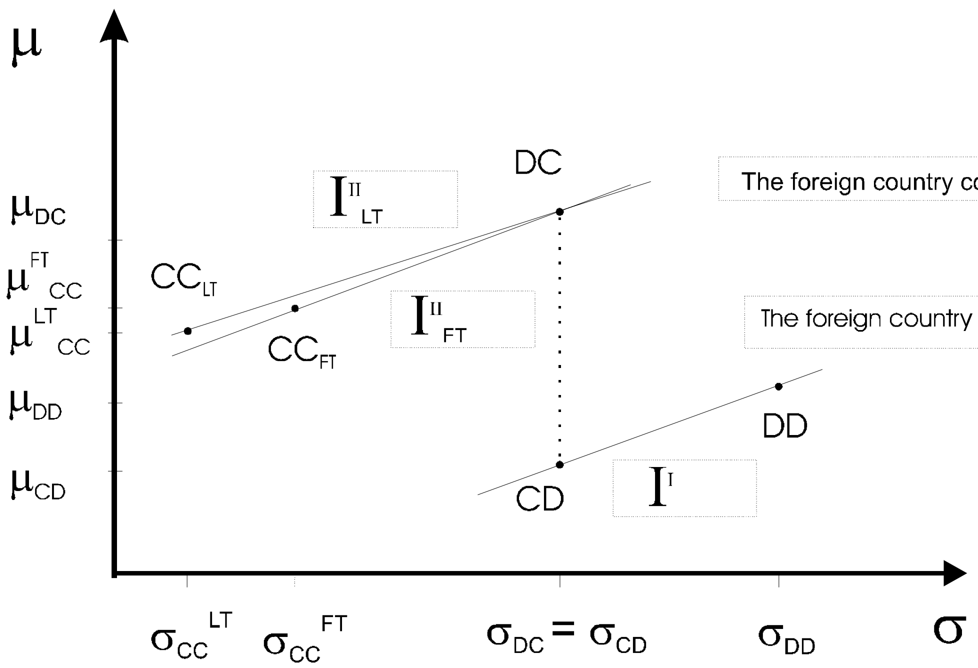

Figure 2: Designing an international environmental treaty. Case 2: $\alpha_{CCFT}^{min} > \alpha_{C}^{min} > \alpha_{CCLT}^{min}$.

According to figure 2, as a result of (7), the FT-curve is now steeper than the LT-curve. Thus given case 2, $\alpha_{CCFT}^{min} > \alpha_{C}^{min} > \alpha_{CCLT}^{min}$ holds.[24] Consequently, opposed to what was said in section 3.1. above, the indifferent country having α equal to α_C^{min} ($\alpha \cong \alpha_C^{min}$) now plays the No Conflict game in the LT-case and the Chicken in the FT-case. The reason is that in the case of free trade the disadvantages of the higher sway of the outcomes here overcompensate the advantages of the higher mean.

Thus, in general, one can not say which design of trade regime is the most co-operative one. Whether it is a regime allowing for free trade or a regime limiting trade by a cap, critically depends on the assessment of the stochastic parameters as well as the country-specific risk preferences.

3.3. The co-operative push of emission permits in the light of country-specific risk attitudes

In reality, it is very suggestive that nations differ in their country-specific risk attitudes. In consequence, as psychological findings suggest, they are also expected to differ in their national assessment of the stochastic risk (here: the assessment of μ and σ).[25]

In general nations are faced with a variety of cost-benefit analysis estimating the national welfare situation according to different scenarios of emission behaviour and ecological development.[26] Dependent on the national belief which of these case studies is the most plausible one, the decision whether to co-operate or not is made. Analysing the Kyoto negotiations, it is obvious that the risk of hot air-trading did not play the pre-dominant role for determining the position of the Umbrella group on the design of the permit regime while it was different for the countries of the Bubble group. This leads to the suggestion that the Umbrella group is less risk averse than the Bubble group i.e., $\alpha^{Bubble} > \alpha^{Umbrella}$ may hold.[27]

[24] If this is actually the case is an empirical question which can not be answered within this theoretical paper. The answer will critically depend on which effect, the efficiency aspect on the side of the means or the accuracy effect on the side of the spreads, is pre-dominant.

[25] E.g. see the findings of Festinger (1967, 1980) and Lopes (1987) leading to the conclusion that the individual risk attitudes determine the search for information and how they are dealt with.

[26] Regarding the issue of climate change e.g. see Nordhaus (1994), Manne/Richels (1999) and the literature cited there.

[27] In this context also think of the risk preferences of the Russian Federation (belonging to the Umbrella group) which is willing to import the nuclear waste of other European countries (as of Germany belonging to the Bubble group) that are unwilling to face the risk of nuclear waste deposits in their own country.

Moreover, since the risk of hot air-trading did matter for the Bubble group but not for the Umbrella group, we may have a country-specific assessment of the threshold values, too. Neglecting the risk of hot air-trading by the Umbrella group but not by the Bubble countries we may have $\alpha_{CCFT}^{min} < \alpha_{CCLT}^{min}$ for the first group and $\alpha_{CCFT}^{min} > \alpha_{CCLT}^{min}$ for the second.

Supposing that $\alpha_{CCLT}^{min} < \alpha_{CCFT}^{min} < \alpha^{Bubble}$ holds, the Bubble countries - independent of the design of the trade regime - face incentives to co-operate. However, since a lower threshold value implies a higher preference value for the co-operative measure under consideration, the Bubble countries favour the regime with trade restrictions. On the other hand, given that $\alpha_{CCFT}^{min} < \alpha^{Umbrella} < \alpha_{CCLT}^{min}$ holds, the Umbrella group is willing to co-operate on free trade only. Thus in order to make both groups of countries co-operate, the trading of emission permits should be fully allowed.

In general this leads to the conclusion:

> Improving the possibility of co-operation requires to set the rules of the agreement with regard to the threshold values of the country showing the lowest intensity of risk aversion.

The reason is that to induce a country with low risk aversion to co-operate it is necessary to push the threshold in this country down. The price of enlarging the agreement consequently is that less risk averse countries are able to „dictate“ the rules of the game (the mechanism design of the protocol).

This result, already derived in the paper of Endres/Ohl (2001), seems to be confirmed by the outcome of the climate negotiations in Marrakech 2001:
On the way to Marrakech the US stepped out of the Kyoto protocol after the election of George Bush for president. This strengthened the position of the rest of the Umbrella group (especially that of Japan and Russia). Since these countries aimed at a regime allowing for free trade of emission permits, ratification of the Kyoto protocol only became feasible with a concession of the Bubble countries. In order to set the Kyoto Protocol in force - which requires a minimum participation of 55 countries named in annex I of the Framework Convention on Climate Change – in the end, the Europeans had to give in their tight position

on the trade regime. According to the results of Marrakech the trading of the whole amount of emission permits is on the way for ratification, now.

So why then - although the Bubble gave in their position on the design of the trade regime – do the US still stay out of the Kyoto protocol?
National risk attitudes in general have to be taken for given. However political change (as in the US by the election of George Bush) usually comes up with a change in attitude as well. Comparing the former president Bill Clinton and the challenger of Bush, Al Gore, there are no doubts that George Bush puts a lower weight to ecological concerns than Gore and Clinton. Thus it is very suggestive that with the election of Bush a shift in the national risk attitude of the US did happen. Consequently the intensity of risk aversion in the US now may be lower than the threshold values so that the prisoners' dilemma for this country remains unsolved.

5. Summary and policy conclusions

In a static setting the focus was on two countries suffering from global environmental risks. It was shown how the chances for international co-operation on the one hand depend on the characteristics of the national welfare distribution (the means μ and the standard deviations σ) and on the other hand on the national attitudes towards risk (α). Given a dichotomous policy choice (co-operation versus defection) national risk attitudes were distinguished according to their cooperative power i.e., according to their relation to the criteria-specific thresholds α_C^{min} and α_{CC}^{min}. If the actual intensities of national risk preferences pass at least on of the threshold values, an incentive to co-operate exists.

The thresholds are determined by the characteristics of the national welfare distribution (here: given in terms of μ and σ). The order of expected welfare μ in each home country was assumed to follow the incentive structure of a prisoners' dilemma game. Regarding the global alliance of risk, σ was said to decrease with each cooperative contribution. Considering these assumptions both thresholds are positive. Thus, in this setting, only a sufficient intensity of risk aversion is able to foster international environmental co-operation. Given the national intensity of risk aversion different types of games evolve in dependent of the relation of the threshold values, i.e. whether α_C^{min} is higher or lower than α_{CC}^{min}, respectively (as shown by table 1 in section 3).

In the case of *manmade* environmental risks, μ and σ depend on measures of risk policy that alter the level of damage as well as of damage probability (endogenous risks). Consequently environmental policy is able to stimulate international co-operation by minimising the threshold values i.e., by a shift of the endogenous parameters μ and σ. With it the policy design is able to select either a coordination- or a dilemma game.

Considering the climate negotiations it was shown that in the case of nations differing in their intensity of risk aversion as well as their assessment of the threshold values (the stochastic parameters μ and σ), the enlargement of environmental co-operation may require to set the rules of emissions trading as foreseen by the Kyoto protocol so as to push the threshold of the country with the lowest risk aversion as far down as possible. Hence the desire of international coalition formation could strengthen the position of countries with low risk aversion. In order to make these countries co-operate it might be necessary to let them "dictate" the rules of the game.

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Inducing Environmental Co-operation by the Design of Emission Permits

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