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HWWA DISCUSSION PAPER

190

Hamburgisches Welt-Wirtschafts-Archiv (HWWA)
Hamburg Institute of International Economics
2002
ISSN 1616-4814

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- Arbeitsgemeinschaft deutscher wirtschaftswissenschaftlicher Forschungsinstitute (ARGE)
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Risk Aversion - a Necessary Condition for Limiting Global Environmental Risks?

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This paper has been prepared within the Research Programme „International Climate Policy“ of HWWA.
The author is indebted to Prof. Dr. Alfred Endres, University of Hagen, and PD Carsten Hefeker, HWWA, for their comments on an earlier draft of this paper.

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Edited by the Department
World Economy
Head: Dr. Carsten Hefeker

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ABSTRACT

Standard risk economic analysis suggests that global environmental risk is lower in the case of risk aversion than in the case of risk neutrality or risk seeking. Maybe the reason why the Advisory Council of the German Government on Global Environmental Change (WBGU) explicitly recommends to behave as a risk averter when dealing with problems of global risk management. However risk aversion not always guaranties the limitation of a global pollutant, like CO2.

To show this the paper focuses on two different landscapes of risk that are motivated by aspects of ecological vulnerability of the nations as well as the country-specific abilities to cope with environmental change. Each is defined in terms of the means μ and of the standard deviation σ of the national welfare distributions in different states of emission behaviour. The nations under consideration are either risk neutral, risk averse or risk seeking and are sovereign in taking measures of global risk reduction. Following the assumption of expected utility maximisation it is revealed that taking and enforcing measures of risk reduction critically depend on the interplay of the subjective risk preferences and the landscape of risk induced by the effects of global risk control. Hence, given the national risk preferences, it is the landscape of risk that determines the co-operative power of national risk attitudes and with it attributes the nations as environmental-friendly or not.

ZUSAMMENFASSUNG

Risikoökonomische Analysen lassen den Schluss zu, dass die Begrenzung globaler Umweltrisiken im Fall der Risikoscheu auf einem höheren Niveau erfolgt als unter Risikoneutralität oder Risikofreude. Möglicherweise empfiehlt deshalb auch der Wissenschaftliche Beirat der Bundesregierung Globale Umweltveränderung (WBGU 2000) bei der globalen Risikobegrenzung eine risikoscheue Haltung einzunehmen. Die vorliegende Analyse zeigt jedoch, dass eine risikoscheue Haltung keine Garantie für die Verringerung globaler Schadstoffe, etwa von CO_2, ist.

Betrachtet werden zwei Risikolandschaften, die sich durch unterschiedliche Risiko-Ertragsstrukturen auszeichnen. Die Ursache sind länderspezifische Betroffenheitslagen im Fall einer Risikofreisetzung sowie nationale Unterschiede bei der Risikobewältigung. In den Risikolandschaften agieren zwei Länder, die souverän über den Beitritt zu einem internationalen Umweltschutzabkommen entscheiden. Jedes Land optimiert entsprechend seiner länderindividuellen Risikopräferenz (die risikoscheu, risikoneutral oder risikofreudig ausgeprägt sein kann) die jeweils nationale Wohlfahrtslage. Dabei wird deutlich, dass der Beitritt zu einem internationalen Umweltschutzabkommen und die Umsetzung der damit verbundenen Pflichten wesentlich davon abhängen, ob die „subjektive“ Risikobewertung durch die Risikopräferenzen der Staaten mit den „objektiven“ (d.h. von Experten geschätzten) Risiko-Ertragsstrukturen harmonieren. Daraus ergibt sich, dass bei gegebener Risikohaltung der Staaten, letztlich der Typ der vorliegenden Risikolandschaft über die kooperationsfördernde Wirkung des Risikoverhaltens bestimmt und in Folge auch festlegt, welchen Staaten das Attribut der Umweltfreundlichkeit und welchen das des Freifahrers zufällt.

1 Introduction

The Globalisation of environmental risks, e.g. arising from the emission of greenhouse gases, calls for internationally co-ordinated measures of risk management. For Germany the Advisory Council of the German Government on Global Environmental Change (WBGU 2000) recommends to behave as a risk-averter when discussing and taking measures of global risk control. Taking standard risk economic analysis into account one might argue that in this case environmental risk will be lower than in the case of risk neutrality or risk seeking (e.g., see Siebert 1998).

However Kahneman and Tversky (1979) point out that the risk seeking attitude may dominant in cases where losses are involved. Focusing on the provision of a global public good, here: environmental quality, participating as a free rider from the provision of the good by others (the co-operating party) usually comes up with a higher payoff than in the case of sharing the burden as a member of the co-operating party. Thus the choice of environmental co-operation might be perceived as a losing deal and consequently (as the findings of Kahneman and Tversky suggest) be made in accordance with the risk seeking attitude.[1]

The risk seeking attitude is also triggered off in cases where a certain aspiration level (regarding a minimum payoff) is not achieved by choices under risk aversion. In this case even decision makers who are risk averse in nature are expected to offset this failure by risk seeking choices (Lopes/Schneider 1986, Lopes 1987). This kind of behaviour (if at all) is most likely to arise in the developing part of the world. There the basic needs are far from being satisfied. Thus although these countries might be seriously harmed by global environmental change they might not be willing to take over measures of global risk control as reflected by the assumption of risk aversion.[2] Hence, all in all, the assumption of risk aversion may not be followed in any case. With it the chances of environmental co-operation might be reduced.

The paper at hand however shows that even the assumption of risk aversion does not always favour the control of global pollutants, like the greenhouse gases, nor that it

1 For a discussion of this issue in the context of environmental change also see e.g. Eismont/Welsch 1996, Welsch 1995.

2 That poverty causes blindness of risk is also pointed out by sociologists. Beck (1986) for example gives some evidence for an import of hazardous wastes and chemical risks due to the social hardship of developing countries. Also think of a country in transition as Russia who is willing to import the nuclear waste from other industrialized countries.

guaranties to protect the global commons at all. Actually (at least in theory) there are cases where the risk seeking attitude does better in terms of environmental co-operation than risk aversion. Consequently risk aversion is no necessary condition for the limitation of global environmental risks. Thus there is a chance to make the developing countries co-operate even if their risk preferences show a flavour of the risk seeking attitude.

The paper proceeds as follows. *Section II* briefly summarises the nature of global environmental problems. *Section III* introduces the national policy choice given that nations face different landscapes of risk, here: defined in terms of the means μ and the standard deviation σ of the national welfare distributions. *Section IV* concentrates on the incentives for environmental coalition formation presupposing that nations are able to develop country-specific attitudes towards risk (national spread preferences). In *section V* it is shown that environmental co-operation might take place a) *either* among risk averse *or* risk seeking countries, b) among a *joint* coalition of *both* groups of countries or c) that environmental co-operation fails *at all* irrespective of the national risk attitudes. The paper closes with an overview of the main findings (*Section VI*).

2 The Nature of Global Environmental Risk

To date global environmental change to a large extend is anthropogenically caused e.g., by excessive emission release. In cases where global pollutants completely diffuse in the atmosphere, as for example the greenhouse gases, we first have to realise that nations form a *global alliance of risk* of which none of it can be excluded (problem of public good; e.g. Dasgupta 1990). In this case, the environmental damages nations suffer and the probabilities with which these damages occur depend upon the *aggregate* countries' emissions.

Dependent on the type of global pollutant we are dealing with, the impact of the emission behaviour of mankind on the ecological vulnerability of nations has to be qualified either by a linear or a non linear relationship. However not in all the cases the functional relation is clear cut. Regarding global warming for example, it is to date unclear if there exists a critical threshold value of emission concentration (critical load), the transgression of which would lead to global catastrophe (e.g. Roughgarden/Schneider 1999, Nordhaus 1994). On the other hand it is commonly agreed that if there exists a critical load, it is likely to be relevant in the long rather than

in the short or intermediate run (e.g. Manne/Richels 1999, Pizer 1999). Consequently, the Advisory Council of the German Government on Global Environmental Change (WBGU 2000) characterizes global warming by two different types of risk: one conventional (intermediate) and one catastrophic (long run).

In cases were global environmental risk is of the conventional type, it is usually assumed that environmental damage continuously varies with the level of emissions.[1] If on the other hand environmental risk is catastrophic, we have to give attention to extreme form of damages. The catastrophic type of risk usually occurs with a low probability while showing a high potential of (sometimes irreversible) damages. Focusing on this type of risk, the consideration of option values and of choice anomalies are able to play a crucial role when assessing the advantages and disadvantages of global risk management.[2]

Of course, if risk is of the conventional or the catastrophic type is an empirical question which has to be answered in dependence of the type of global environmental problem we are dealing with. However what we observe in international negotiations is (e.g., when negotiating the climate convention) that the time horizon of the decision makers (at least for some of the decision makers) has to be qualified as short-sighted. Especially in the case of global warming, main attention still is given to the costs of enforcing the reduction targets whereas the defence of possible catastrophic events in the future has been of minor interest yet.[3] With it (at least some of the) environmental problems seem to be dealt with *as if* they were of the conventional type. In such cases it is completely appropriate to model the decision behaviour of nations, here: on whether to take part in an international agreement on environmental protection or not, in accordance with the von Neumann-Morgenstern approach (expected utility approach; von Neumann/Morgenstern 1944).

1 See e.g. Endres 2000, Kolstad 2000 where expected damage is a well behaved function of emissions with positive first and second order derivatives.

2 For a modeling of the catastrophic type of risk see e.g. Chichilnisky 2000, Chichilnisky/Heal 1998, Querner 1994. Moreover see Fisher 2000 for the application of (quasi) option values in the context of environmental risk. Additionally see e.g. Allais 1953, Kahneman/Tversky 1981, Machina 1997 for a discussion of the so-called choice anomalies when dealing with choices under uncertainty.

3 Maybe the reason why concentration of greenhouse gases in the atmosphere did not influence the definition of the national emission reduction targets as specified in the Kyoto agreement of 1997 (e.g. see Oberthür/Ott 1999).

3 National Policy Choice

In the context of global risk management the idea of a sustainable development claims to pay attention to ecological, economic as well as social impacts of global risk control. Regarding this idea, analysing the problems of global risk reduction calls for a linkage of ecological and societal concerns. Consequently nations are not expected to follow ecological considerations only. It is even more likely that countries give the highest priority to economic aspects and in the first place consider the effects of global emission control on the national welfare situation. The paper at hand therefore specifies the effects of global risk control in terms of expected national welfare μ (*subsection 1*) and in terms of the respective standard deviation σ (*subsection 2*). In order to judge the risky options under consideration s*ubsection 3* closes with an introduction of the decision criterion, here: the mean-variance principle following the axioms of the expected utility approach.

3.1 Expected national welfare μ

Up to now there is no automatism working making nations act in favour of environmental concerns. Among sovereign nations it is still a voluntary task to take measures of global risk control and to hold on to a national duty ruled by international treaties. Hence usually enforcement of an agreement on global risk management is only assured if the impact of national emission reduction on each countries' welfare is in favour of environmental protection (problem of self-enforcement, e.g. see Barrett 1994, 1999).

In the case of global warming (as for many other environmental issues, too) the costs of emission control, at least in the short and intermediate run, are estimated to be higher than expected savings from damage reduction (e.g. see Benedick 1999). Therefore the polluting countries are challenged by the national incentives to free ride. That is, they aim at the participation of benefits arising from emission reductions taken by other countries without sharing the costs of emission control. Hence the problems of limiting a global pollutant, like CO_2, are often characterised by prisoners' dilemma games.[1] In

1 For the prisoners' dilemma and other types of games (an introduction into game theory in general) see e.g. Luce/Raiffa 1989, Eichberger 1998. In the context of global environmental risks also see Finus 2001, Endres/Ohl 2001.

terms of expected national welfare (μ) nations then face the following ranking of desired strategy choice:

$$\mu_{DC} > \mu_{CC} > \mu_{DD} > \mu_{CD} \quad => \quad \mu_D > \mu_C \qquad \text{(PD)}$$

The subscripts of μ show the activity combinations to which the means refer. The first subscript points to the action chosen by the home country, the second to that of the foreign country.[1] Two activities for each country are considered: the choice of co-operation (C) and the choice of defection (D). In the case of co-operation nations take part in a treaty on global emissions control. In the case of defection they choose not to comply with the treaty. Supposing a pretentious definition of the national target level, emissions are thus expected to be lower in the case of co-operation than in the case of defection. Given this setting, the ranking of the means states that independent of the foreign country's choice, the home country's expected welfare is highest in the case of its defection ($\mu_{DC} > \mu_{CC}$ and $\mu_{DD} > \mu_{CD}$). With it, the focus is on a worst case scenario for international coalition formation: the choice of defection dominates the choice of co-operation. This is the model of the prisoners' dilemma (PD) as given by $\mu_D > \mu_C$.[2]

However behaviour of nations is not motivated by expected national welfare maximisation only. Countries' preferences according to different measures of risk (for a survey see e.g. Brachinger/Weber 1997), as the spread of the national welfare distributions, may also play a crucial role in international negotiations.

3.2 The standard deviation σ

The standard deviation σ focuses on the spread of the outcomes (here: national welfare in different states of the world) around the mean μ. Considering μ and σ, the focus is on two essential parameters assessed by the natural sciences in order to indicate global environmental change. Unfortunately evidence on the relationship between the variability of damages (welfare) and the level of emissions is fragmentary at best. Moreover in areas of application where we have some evidence, it seems to point into

1 Of course the limitation of global environmental risk calls for co-operation among a number of countries larger than two. However focusing on two countries only (which also could be interpreted as two groups of countries, like the „EU-Bubble" and the „Umbrella group" in climate negotiations) is sufficient to explain the strategic considerations of nations aiming at the provision of public goods (here: environmental quality).

2 Regarding real world phenomena, the ranking of the means according to the prisoners' dilemma might not hold in any case. However these cases are neglected, here. The reason is that the problem of establishing international co-operation (at least partly) dissolves with relaxing the assumption of expected welfare following the incentives of the prisoners' dilemma game. Thus the most challenging case is the worst case scenario for environmental co-operation as introduced above.

different directions. Therefore the correlation of the mean and the spread is not clear cut: [1]

A case where the development of the means and the standard deviation seems to be positive correlated is rain: With the emission of greenhouse gases the average amount of rain per incidence of rainfall increased. At the same time did periods of drought on the one hand and of flash floods on the other hand. Thus, regarding rainfall, we have a case where the mean as well as the standard deviation seem to have increased with the level of emissions. On the other hand, the development of the average temperature and its daily variability constitute a counter example: Even though average temperature increased, its daily amplitude decreased, pointing to a negative correlation of the development of the mean and the spread. Hence, regarding both indicators (rainfall and temperature) simultaneously, we can't say if the aggregated risk of global warming in terms of the (aggregated) standard deviation increases or decreases.[2]

Moreover dealing with aspects of risk management (how nations cope with environmental change), we have to focus on the effects of emissions *reduction*; i.e. on the expected trends of a change in the means μ and the standard deviation σ when emissions are going to *de*crease with global emission control. Modelling the global alliance of risk thus has to answer the question if the observed trends by the natural sciences (the ecological risks) are reversal or at least partial reversal.

In most of the cases the answer to this question depends on the time horizon we are looking at. In the paper at hand the focus is on the short and intermediate run. In this case the assumption of (partial) reversibility is primarily expected to hold for environmental risks caused by the short living pollutants. Regarding persistent pollutants (that stay in the atmosphere rather long than short, as the greenhouse gases), at first sight, this seems not to be the case. However, different from the natural scientists focusing on ecological considerations only (a safe minimum standard regarding environmental concern), politicians also take the costs of enforcing a standard into account. That is they usually make their decision in terms of the national welfare implications by weighing the costs and benefits of environmental protection. Hence the shape of the national welfare distribution is not determined by the ecological vulnerability of nations only (i.e. by natural influences mainly affecting the spread of

1 The ecological interpretations given in this section mainly draw upon Endres/Ohl 2001and this authors correspondence with Hartmut Graßl (Max Planck Institute and University of Hamburg) who patiently explained the scientific complications when modeling the global alliance of risk.

2 To calculate the aggregated risk is necessary since the developments, here: of rain fall patterns and temperature simultaneously take place and therefore can't be isolated from each other.

the national damage distribution), but also by economic considerations affecting the costs of national emission control and/or the monetary evaluation of national damages (e.g. depending on income, the national growth rate, technological progress etc.). Thus, even in the case of persistent pollutants and a short-sighted time horizon of the political decision makers, the standard deviation is able to vary with national policy choice (here: C and D). Moreover it follows that even in cases where the sway of the welfare distribution as a consequence of ecological considerations stays constant, the decision on whether to co-operate or not, is able to alter the characteristics of the national welfare distributions (μ and σ). Thus in any case (persistent and non persistent pollutants) the establishment of environmental regimes aiming at the control of global pollutants may affect the means as well as the spread of each national welfare distribution.

However regarding both: the ecological and economical uncertainties, all the more the development of the mean and the spread remains undetermined. Additionally since nations differ in ecological vulnerability as well as their abilities to cope with environmental change (because of differences e.g. in technological efficiency and know how), the correlation of the mean and the spread is able to differ across countries, too. Therefore, in order to touch the general as well as the country-specific uncertainties, the modelling of the global alliance of risk distinguishes two landscapes of environmental risk:

a) Risk Landscape 1

$\sigma_{DD}>\sigma_{CD}$ and $\sigma_{DC}>\sigma_{CC}$ => $\sigma_D>\sigma_C$ (RL1)

b) Risk Landscape 2

$\sigma_{DD}<\sigma_{CD}$ and $\sigma_{DC}<\sigma_{CC}$ => $\sigma_D<\sigma_C$ (RL2)

RL1 and RL2 deliver varying expectations on the development of the shape of the national welfare distribution. In *risk landscape one* (RL1) the standard deviation is assumed to decrease with each unit of emission abatement; in *risk landscape two* (RL2) the standard deviation is expected to increase with each unit of emission reduction. Since emissions completely diffuse in the atmosphere, these assumptions hold irrespective of which nation is acting. Consequently the second subscript pointing to the foreign policy choice can be disregarded, here ($\sigma_D>\sigma_C$ and $\sigma_D<\sigma_C$ respectively).

Both landscapes have in common that irrespective of which development the standard deviation takes, the respective means are presupposed to be lower in the case of co-operation than in the case of defection. That is, regarding the means (μ), each landscape

of risk (RL1 and RL2) follows the incentive structure of the prisoners' dilemma (PD) as introduced in subsection 1 above.

With the modelling of the national welfare expectation (PD) as well as the respective spread behaviour (RL1 and RL2), we are able to reflect the country-specific vulnerability regarding environmental change as well as the country-specific abilities to cope with it. How these aspects may feed back to the national willingness to co-operate on measures of global risk control is outlaid with reference to the quadratic μ-σ-criterion introduced below.

3.3 The μ-σ- principle

In order to judge the risky options under consideration nations are presupposed to behave *as if* they follow national spread preferences.[1] In this case the countries either seek to minimise volatility of the national welfare distribution (risk aversion), are insensitive towards the possible sway of welfare (risk neutrality) or, explicitly welcome the variation of welfare (risk seeking). These spread preferences are recorded by the well established mean-variance-principle (μ-σ-criterion):[2]

$$\phi = \mu - \alpha (\mu^2+\sigma^2) \text{ with} \quad (1)$$

$$\partial\phi/\partial\mu>0 \; \forall\alpha \text{ and} \quad (2)$$

$$\partial\phi/\partial\sigma<0 \text{ for risk aversion } (\alpha>0) \quad (3a)$$

$$\partial\phi/\partial\sigma=0 \text{ for risk neutrality } (\alpha=0) \quad (3b)$$

$$\partial\phi/\partial\sigma>0 \text{ for risk seeking } (\alpha<0) \quad (3c)$$

1 That nations (their political decision makers) indeed may have internalized some kind of spread preferences is e.g. suggested by the definition of the suppositions for the enforcement of the European monetary union. Moreover societal discussions reveal that the stability of money, of income, of prices as well as the climate stability play a crucial role. Additionally, as argued above, the developments of the means and the spread assessed by the natural scientist for different indicators of global environmental change provide the ecological data on which the decision on the necessity of global risk management is based. Consequently politicians (at least to some extend) may decide upon co-operation and defection in terms of μ and σ as well.

2 The advantages of this criterion are its solid axiomatic foundation and that it has been successfully applied in a number of fields (e.g., in investment and portfolio theory). Compared to other risk utility functions it moreover has the advantage of explicitly dealing with the stochastic parameters of the model. Additionally, using the μ-σ-criterion does not require the knowledge of the probability distribution as a whole (i.e., knowledge of each single event). Its application „only" demands for the assessment of two characteristic parameters (μ and σ). Although there are some good arguments for

Decision function (1) with preference value ϕ indicates the national welfare in terms of risk-utility. (2) requires an increase of the preference value if the mean rises, ceteris paribus.[1] Depending on the national risk attitude (α), ϕ adapts to changes of σ: For risk-averse countries ($\alpha>0$) ϕ decreases if σ rises (3a); given risk neutrality ($\alpha=0$) σ has no impact on the preference value (3b); and regarding the risk-loving nations ($\alpha<0$) ϕ and σ develop in the same direction (3c).

4 The co-operative power of national risk preferences

In order to answer the question, if risk aversion is a necessary condition for a governance of the global commons, we have to clarify which attitude (α) is in favor of environmental protection, here: performed by the choice of co-operation. Given that nations seek to maximize national risk utility (i.e. they seek to maximize ϕ) the choice of co-operation is to be expected if the preference value for co-operation (ϕ_C) is higher than (or at least equal to) the preference value for defection (ϕ_D). From $\phi_C \geq \phi_D$ it follows:

$$|\alpha| \geq (\mu_D-\mu_C) / |(\mu_D)^2-(\mu_C)^2+ (\sigma_D)^2-(\sigma_C)^2| \equiv |\alpha_{Cmin}| \qquad (4)$$

Expression (4) defines the critical attitude of risk preferences (α_{Cmin}) for which incentives to co-operate exist.[2] According to the order of the means as given by (PD): $\mu_D>\mu_C$, the threshold value α_{Cmin} is unequal to zero; i.e. $\alpha_{Cmin}\neq 0 \Rightarrow |\alpha_{Cmin}|>0$ holds. Consequently regarding the case of risk neutrality ($\alpha=0$) independent of the emerging landscape of risk (see RL1 and RL2 above) the choice of defection always dominates the choice of co-operation. However the possibility of international co-operation rises as soon as countries are of the risk seeking type ($\alpha<0$) or behave as a risk averter ($\alpha>0$).

Whether it is risk aversion or the risk seeking attitude that actually fosters environmental protection critically depends on the sign of α_{Cmin}: Referring to risk

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using the μ-σ-criterion the method applied here could of course be introduced to other decision criteria and measures of risk (e.g. the semi-variance).

1 Thus, (2) implicitly requires that the term $-\alpha\mu^2$ in decision function (1) does not dominate; therefore, in accordance with the axioms of the expected utility approach, only the upward sloping part of the risk utility function is to be considered. For a discussion of the interrelation of the classical μ-σ-criteria and the risk utility functions of the von Neumann-Morgenstern-type see e.g. Huang/Litzenberger 1988, Sinn 1989, 1990. Referring to a quadratic utility function, here, implies that nations treat their risky options as inferior goods. For the use of a linear function see Endres/Ohl 2001, pointing out that the quadratic version is not crucially for the results derived in the paper at hand.

2 For a detailed discussion of the underlying game theoretic considerations when determining the critical risk attitude see Endres/Ohl 2001. The resulting typology of co-operative behavior is given in the appendix.

landscape 1 (RL1), $\sigma_D>\sigma_C$ as well as $\mu_D>\mu_C$ holds. Consequently α_{Cmin} takes a positive value. Thus it is the risk avers countries that may favor the choice of co-operation. Considering risk landscape 2 (RL2), still $\mu_D>\mu_C$ holds. However because of $\sigma_D<\sigma_C$ the threshold α_{Cmin} either takes a positive or a negative value. But, regarding the assumption of rational choice (2) positive values are excluded.[1] Hence given RL2, it is the risk seeking nations ($\alpha<0$) facing incentives for global emission control.

Dependent on the arising landscape of risk we thus have the following results:

a) Risk landscape 1

Given the countries are in face of risk landscape 1 - leading to $\alpha_{Cmin}>0$ - neither risk neutrality ($\alpha=0$) nor risk seeking behaviour ($\alpha<0$) calls for international co-operation. However if countries interact as risk averters ($\alpha>0$) and their intensities of risk aversion overleap the threshold value ($\alpha>\alpha_{Cmin}>0$) incentives for co-ordinated action arise. That is because risk averse nations are unwilling to accept improvements in expected national welfare if the price they have to pay - the increase in the spread - is too high.

b) Risk landscape 2

Considering risk landscape 2 - leading to $\alpha_{Cmin}<0$ - it is only the risk seeking countries ($\alpha<0$) for which incentives to co-operate exist. For environmental co-operation actually to take place, the intensity of the risk seeking attitude has to undershoot the threshold value ($\alpha<\alpha_{Cmin}<0$). Consequently nations acting under risk aversion ($\alpha>0$) or risk neutrality ($\alpha=0$) do not face any incentives for global emission control. The reason is that environmental co-operation lowers the national welfare expectation and at the same time increases the spread of the national welfare distributions which for these countries is out of desire constantly.

Thus, it is the risk averse nations ($\alpha>0$) *as well as* the risk seeking ones ($\alpha<0$) that might have incentives to co-ordinate on measures of global risk management. Whether it is the risk averse or the risk seeking countries aiming at a treaty on emission control critically depends on the impact of the policy measure on the shape of the national welfare distribution. This impact is delivered by the sign of the threshold value α_{Cmin} that is determined by the developments of the "objective" risk parameters, μ and σ. Moreover the analyses show that irrespective of which attitude favors emission control,

1 A formal proof is available upon request on the author.

it is the intensities of national risk preferences that have to overleap a certain threshold value to actually induce incentives for environmental co-operation.

Consequently the international propensity to co-operate, on the one hand, depends on the landscape of risk induced by measures of global risk management (the orders of μ and σ) and, on the other hand, on the type and the intensities of national risk preferences (the value of α). Thus given the national risk preferences (α), it is the arising landscape of risk that attributes nations as environmental friendly or not.

5 A typology of international coalition formation

The above analyses point out that it is the landscape of risk that distinguishes national risk preferences in terms of their co-operative power. Since the landscape of risk is able to differ across countries this necessarily implies that international coalition formation presupposes a harmony reign of the national risk attitudes and the developments of the objective risk pattern. Hence recommending to behave according to a uniform risk preferences – even if this recommendation would be followed – is no guaranty for solving problems of global risk management. A finding which is outlined in a graphical analysis below.

Referring to different types of pollutants,[1] case 1 deals with a situation where environmental coalition formation attracts countries having the same risk attitude (figure 1). Case 2 lays out that co-operation is able to take place among countries acting under different risk preferences (figure 2). Finally case 3 draws a worst case scenario for international coalition formation: Irrespective of the national risk attitude, countries face no incentives for environmental protection at all (figure 3).

1 That might be linked to the assessment of global risks as suggested by the Advisory Council of the German Government on Global Environmental Change (WBGU 2000).

Case 1: Environmental coalition formation among countries having the same risk attitude

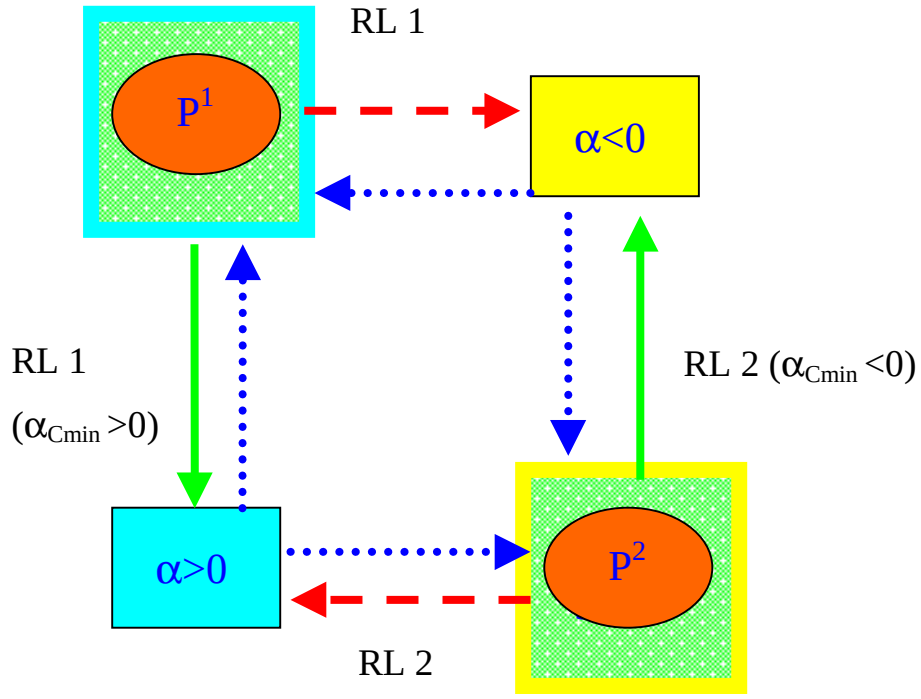

Figure 1: Rule of Risk Selection 1

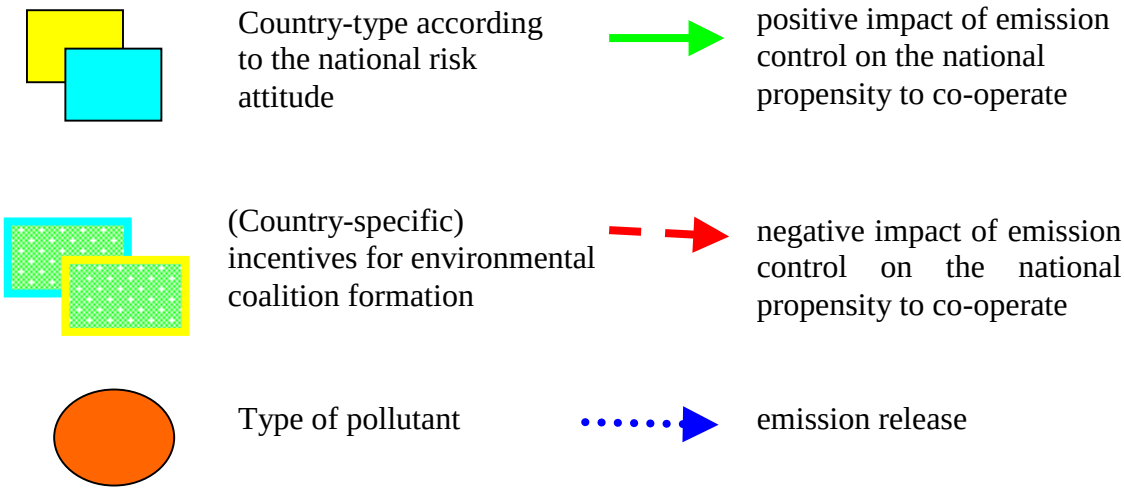

Figure 1 shows two groups of countries one of which is risk averse ($\alpha>0$) and the other risk seeking ($\alpha<0$). Each group of countries emits two types of pollutants (P^1 and P^2). According to figure 1 reduction of P^1 generates risk landscape 1 (Rl 1) in countries with $\alpha>0$ as well as $\alpha<0$. Considering the reduction of P^2, risk landscape 2 (Rl 2) in each of the countries arises. Consequently country group $\alpha>0$ might be interested in the control of P^1 and country group $\alpha<0$ in the control of P^2. If environmental coalition formation actually takes place critically depends on the intensities of the national risk preferences. If the national risk preferences (α) pass the threshold values ($\alpha_{Cmin}>0$, $\alpha_{Cmin}<0$ respectively), a potential for international co-operation exists. Supposing that $\alpha>\alpha_{Cmin}>0$ as well as $\alpha<\alpha_{Cmin}<0$ hold, figure 1 states that countries may have different priorities in global risk management:

1. If emission control centres on the limitation of P^1, international co-operation is feasible among the risk avers countries.
2. If however negotiations aim to control the release of P^2, co-operation is only to be expected among the risk seeking countries.

We hence may have a specialisation in global risk management where a subgroup of countries (here: the risk avers countries, $\alpha>0$) co-operates on the limitation of pollutant type P^1 and the other subgroup of countries (here: the risk loving countries, $\alpha<0$) on the control of pollutant type P^2. This leads to the conclusion that given case 1, the possibility of international co-operation (the possibility of enlarging co-operation) increases if negotiations aim at the control of a basket of different pollutants alternatively than of one type only (as e.g. is the case in climate negotiations).[1]

All in all, this confirms the general result derived in section III above:

It is not only the type and the intensities of national risk preferences that decide upon which action to take, but also the objective risk pattern (the order of μ and σ) induced by emissions control that defines the type of the emerging landscape of risk. Hence it is not always risk aversion that protects the global commons better than any other risk attitude.

1 Linking case 1 to the issue of climate negotiations does not state that the control of different greenhouse gases indeed constitutes different landscapes of risk. However it suggests that co-operation might be enlarged by widening the perspective of emission control, i.e. by enlarging the portefeuille of pollutants considered for global risk control.

Case 2: Common interest of environmental coalition formation among countries having different risk attitudes

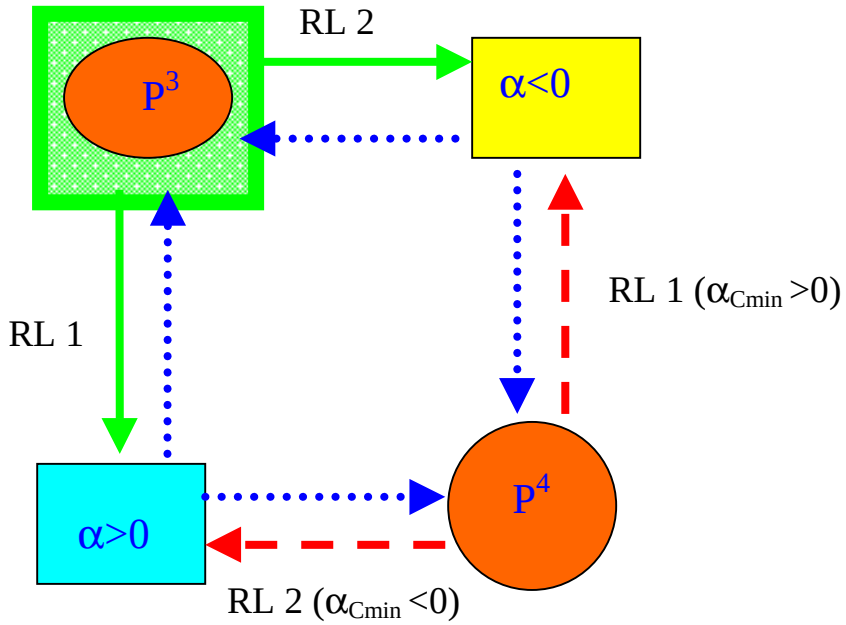

Figure 2: Rule of risk selection 2

As in figure 1 above, the focus is on two groups of countries ($\alpha>0$ and $\alpha<0$) as well as on two types of pollutants (P^3 and P^4). According to figure 2 the reduction of P^3 generates risk landscape 1 in country group $\alpha>0$ and risk landscape 2 in the risk seeking countries ($\alpha<0$). Considering the control of P^4, it is risk landscape 2 that arises in countries with $\alpha>0$ and risk landscape 1 in countries holding $\alpha<0$. Consequently figure 2 shows a common interest of country group $\alpha>0$ *and* $\alpha<0$ to establish a regime on emission control for pollutant type P^3. Additionally we see that international negotiations are expected to fail if the aim is the limitation of pollutant type P^4: *Neither* country group $\alpha>0$ *nor* $\alpha<0$ have incentives to take over measures of global risk control. Thus, given case 2, environmental co-operation only becomes feasible if the aim is at the limitation of P^3 exclusively.

Hence negotiating a treaty allowing for the control of different types of pollutants (here: P^3 and P^4) alternatively, here, is unable to enlarge environmental coalition formation.

Moreover recommending a treaty aiming at the control of both types of pollutants simultaneously is expected to fail. Given the setting of case 2, the possibility of international coalition formation improves only if the treaty calls for a limitation of P^3 while allowing the emission of P^4. A negotiation feature we e.g. observe under the agreement on the ban of the organic pollutants (POPs) as of 2001 that still allows the use of DDT in some of the developing countries.[1]

Regarding the control of P^4 we thus have indeed the result that only a switch in risk preferences is able to foster measures of risk management. However it is not only the switch from the risk seeking to the risk averse attitude but also the switch from the risk averse to the risk seeking preferences that is able to improve the chances for pollution control (here: of pollutant type P^4). Thus it is the type of pollutant considered to control that decides upon the management power of risk attitudes by determining the national landscape of risk. With it case 2 points out that in reality a pluralism of risk preferences is able to do better in solving problems of global risk management (especially when pollutants cause different landscapes of risk) than one uniform risk attitude around the globe.

1 Regarding the ban of the POPs the developing countries using DDT for Malaria defense were unwilling to co-operate on an agreement prohibiting the use of DDT. Therefore for these countries an exception on the use of DDT for Malaria defense was made.

Case 3: Failing of global environmental co-operation

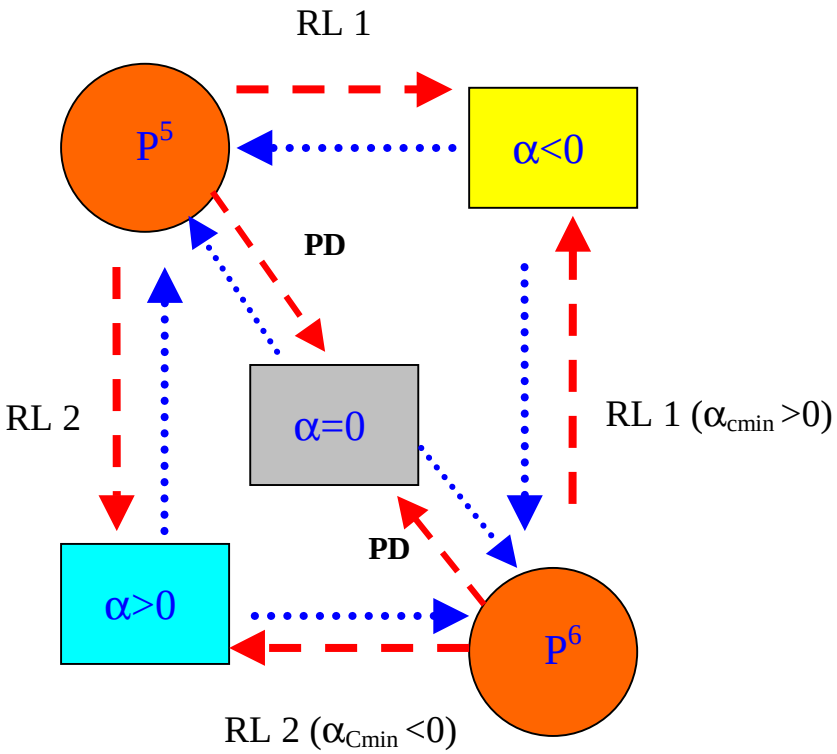

Figure 3: Rule of risk selection 3

Case 3 now considers the whole range of national risk attitudes, i.e. the case of risk aversion ($\alpha>0$), of risk seeking ($\alpha<0$) as well as of risk neutrality ($\alpha=0$). Each of the three country groups under consideration releases pollutants of type P^5 and P^6. Figure 3 lays out that irrespective of the national risk preferences countries may have no incentives to co-operate at all:

Regarding countries acting under risk neutrality ($\alpha=0$) the prisoners' dilemma (PD) is at work ($\mu_D>\mu_C$). These countries always favour the choice of defection irrespective of which landscape of risk arises. Moreover referring to the control of P^5 and P^6 defection is also the dominant choice for countries acting under risk aversion ($\alpha>0$) as well as under the risk seeking attitude ($\alpha<0$). Consequently measures of global risk

management are not expected to be taken at all. The reason is that the effects of global risk reduction are not in line with the country-specific risk preferences. The limitation of P^5 and P^6 each causes risk landscape 1 in country group $\alpha<0$ and risk landscape 2 in country group $\alpha>0$. Thus neither group of countries wishes to take part in an environmental convention irrespective of the type of pollutant (P^5 or P^6) considered for global risk control.

Hence, all in all, there is neither a guarantee that risk aversion protects the global commons better than any other risk attitude nor, that it protects the global commons at all.

6 Summary and Conclusion

The analyses above suggests that given the country-specific risk attitudes, international co-operation depends on the characteristics of the national welfare distributions induced by measures of global risk control.

In the paper at hand the characteristics of national welfare are given by μ and σ, with μ displaying the means and σ the standard deviation of the welfare distribution. Two risky options were considered: the choice of co-operation (C) and the choice of defection (D). In the case of co-operation nations take over measures of global risk reduction. In the case of defection they behave as free riders i.e., they are not expected to join or to comply with a treaty aiming at the reduction of a global pollutant, like CO_2. Dependent on the national policy choice, the order of expected national welfare (μ) was assumed to follow the incentive structure of the prisoners' dilemma game. The spread σ of the respective mean was assumed either to decrease (case of risk landscape 1, RL1) or to increase (case of risk landscape 2, RL2) with each co-operative contribution (here: each unit of emission abatement). Additionally the countries under consideration were presupposed to maximise national risk utility according to the (quadratic) μ-σ-principle.

Given this setting it was shown that international co-operation gets feasible if the intensities of national risk preferences overleap a certain threshold value (α_{Cmin}). The threshold value is determined by the emerging landscape of risk (the order of μ and σ) and could either be positive or negative.

Referring to *risk landscape 1* the threshold takes a positive value ($\alpha_{Cmin}>0$). Thus only risk aversion ($\alpha>0$) is able to foster environmental co-operation. For co-operation

actually to take place, the intensities of national risk aversion have to pass the threshold value, i.e. $\alpha>\alpha_{Cmin}>0$ must hold. If the intensity of national risk aversion falls short of the threshold ($\alpha<\alpha_{Cmin}>0$) internationally coordinated measures are expected to fail. Moreover it follows that co-operation is unattractive, if nations are either of the risk seeking ($\alpha<0$) or of the risk neutral type ($\alpha=0$).

Referring to *risk landscape 2*, the standard deviation σ was presupposed to increase with each cooperative contribution (leading to $\alpha_{Cmin}<0$). Countries facing risk landscape 2 therefore are only expected to join and to hold on to an agreement on global emission control if their risk attitude is of the risk seeking type ($\alpha<0$). In this case for environmental co-operation actually to take place, the risk seeking attitude has to undershoot the threshold value ($\alpha<\alpha_{Cmin}<0$). In any other case (i.e. when $\alpha>\alpha_{Cmin}<0$ holds) incentives for international risk management lack.

Thus in each of the cases it is the involved countries' risk preferences *as well as* the emerging landscapes of risk (the orders of μ and σ) that decide whether the road to environmental co-operation will be taken or not. Given the national risk preferences, it is the type of the global alliance of risk (the development of σ) that decides which kind of risk preferences favour environmental co-operation and which kind of risk preferences do not. If variability of national welfare decreases (increases) with emission reduction, risk aversion (risk seeking behaviour) turns out to be a necessary condition. If, on the other hand, variability of welfare increases (decreases) with emission reduction, risk aversion (risk seeking behaviour) as well as risk neutrality lead to defection. Hence it is the type of the emerging landscape of risk that attributes nations as environmentally friendly or not. Moreover given the landscape of risk, that countries possess the favourable type of risk preferences will not be enough to trigger co-operation. It is an additional prerequisite that this preference is strong enough to overcome a certain threshold value. Only in this case the incentives of the prisoners' dilemma are transformed such that a game of a higher co-operation possibility results.

Hence recommending to behave according to a uniform risk preferences (e.g. as a risk averter) – even if the advise is followed - is no guaranty that countries successfully solve problems of environmental protection. The analyses points out that the performance of national risk preferences regarding the willingness to co-operate critically depends on the landscape of risk induced by measures of risk management.

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APPENDIX:

A TYPOLOGY OF CO-OPERATIVE BEHAVIOUR

The value of the threshold α_C^{min} depends on the foreign country's choice. In table 1 below the second entry in the subscripts points to this country's choice. Hence the threshold α_{CD}^{min} delivers the threshold for unilateral co-operation of the home country (i.e. the case of foreign defection) and α_{CC}^{min} the threshold for bilateral co-operation (i.e. when the home *and* the foreign country co-operate). Referring to the relation of these threshold values and their relation to a home country's risk attitude (α) in absolute terms we get:[1]

Table 1:
A typology of co-operative behaviour

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

1 See Endres/Ohl 2001 for a more detailed analysis of this issue.