Discussion Paper No. 07-064

Climate Policy and Ancillary Benefits

A Survey and Integration into the Modelling of International Negotiations on Climate Change

Karen Pittel and Dirk T.G. Rübbelke

Zentrum für Europäische
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Nontechnical Summary

A main critique concerning the Kyoto Protocol is the lack of inclusion of emission reduction obligations for developing countries. A non-participation of major polluting countries located in the developing world in an ambitious international agreement on climate change represents an immense threat to our planet. This is due to the fact that some developing countries are meanwhile among the main greenhouse gas emitters of the world. China is already the second-largest CO_2 emitter in the world and India is ranked fifth, for example.

Due to the rising importance of developing countries' contribution to climate change, their participation in an international problem-solution approach becomes crucial. Therefore, it is important to detect possible motivations for countries, both developing and industrialized countries, to participate in an international agreement on climate change. In order to analyze and depict aspects which raise the likelihood of countries signing such an agreement, we employ the game-theoretical concept of bimatrices. More precisely, we highlight the positive impact primary and ancillary or secondary benefits of climate policy may have on the outcome of international negotiations on climate change. Primary benefits are the benefits derived from pursuing climate policy's primary aim, which is climate stabilization. In contrast, ancillary benefits are the monetized co-effects of climate policy, such as reductions in local air pollution. As we illustrate in a survey of the literature, ancillary effects are rather miscellaneous.

In order to describe international negotiations on climate change we refer to the game of Chicken. Although the depiction in a bimatrix is a quite simple method, it discloses many important features of negotiation problems. Recently Schleich et al. (2006) employed a normal form game in order to analyse the behaviour of states in international climate policy. Endres and Ohl (2002) also employed bimatrices to analyze international environmental negotiations. As we do, they consider coordination games. The focus of their model is on the effects of different environmental instruments on the negotiation outcome. In contrast we do not distinguish between individual environmental instruments. We regard climate policy in general and not specific policies.

Due to the fact that the properties of ancillary benefits differ significantly from those of primary benefits, interesting consequences result from this inclusion of ancillary benefits in the analysis. So this study identifies ancillary benefits of climate policy to provide important incentives for developing countries to attend an international agreement on climate change.

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A Survey and Integration into the Modelling of International Negotiations on Climate Change

Karen Pittel*
Dirk T.G. Rübbelke**

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Abstract: Currently informal and formal international negotiations on climate change take place in an intensive way since the Kyoto Protocol expires already in 2012. A post-Kyoto regulation to combat global warming is not yet stipulated. Due to rapidly increasing greenhouse gas emission levels, industrialized countries urge major polluters from the developing world like China and India to participate in a future agreement. Whether these developing countries will do so, depends on the prevailing incentives to participate in international climate protection efforts. This paper identifies ancillary benefits of climate policy to provide important incentives to attend a new international protocol and to positively affect the likelihood of accomplishing a post-Kyoto agreement which includes commitments of developing countries.

Keywords: ancillary benefits, climate change, international negotiations, chicken game

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* CER-ETH - Center of Economic Research at ETH Zurich, ZUE F12, 8092 Zurich, Switzerland, email: kpittel@ethz.ch
** Department of Economics, Chemnitz University of Technology, 09107 Chemnitz, Germany, email: dirk.ruebbelke@wirtschaft.tu-chemnitz.de

I. Introduction

A main critique concerning the Kyoto Protocol is the lack of inclusion of emission reduction obligations for developing countries. As Schelling (2002) points out: "There is no likelihood that China, India, Indonesia, Brazil, or Nigeria will fully participate in any greenhouse-gas regime for the next few decades." A non-participation of these developing countries in an ambitious international climate policy represents a major threat to our planet. China is already the second-largest CO_2 emitter in the world and India is ranked fifth. Energy-related CO_2 emissions are forecasted to increase alone in non-OECD Asia from 3,626 million metric tons in 1990 to 15,984 million metric tons in 2030, while in Africa the rise in the same period of time is from 649 million metric tons to 1,733 million metric tons (EIA 2006: 73). While OECD countries emitted 13,150 million metric tons in 2003 and thus the main portion of global CO_2 emissions, in 2030 the non-OECD countries will take the lead with 26,180 million metric tons of CO_2 (EIA 2006: 73).[1]

Consequently, due to the rising importance of developing countries' contribution to climate change, their participation in an international problem-solution approach becomes crucial. This holds regardless of Schelling's sceptical view mentioned above. Therefore, it is important to detect possible motivations for countries, both developing and industrialized countries, to participate in an international agreement on climate change. In order to analyze and depict aspects which raise the likelihood of countries signing such an agreement, we employ the game-theoretical concept of bimatrices. More precisely, we highlight the positive impact primary and ancillary or secondary benefits of climate policy may have on the outcome of international negotiations on climate change. Primary benefits are the benefits derived from pursuing climate policy's primary aim, which is climate stabilization. In contrast, according to the IPCC (2001), ancillary benefits "are the monetized secondary, or side benefits of mitigation policies on problems such as reductions in local air pollution associated with the reduction of fossil fuels, and possibly indirect effects on congestion, land quality, employment, and fuel security." In order to describe international negotiations on climate change we refer to the game of Chicken.

Although the depiction in a bimatrix is a quite simple method, it discloses many important features of negotiation problems. Recently Schleich et al. (2006) employed a normal form game in order to analyse the behaviour of states in international climate policy. More precisely, they show that restricting banking in EU emission trading may essentially constitute a prisoner's dilemma situation for EU member states. Endres and Ohl (2002) also employed bimatrices to analyze international environmental negotiations. As we do, they consider coordination games. Yet, they regard two different types of games: Chicken and

[1] In 2003 the non-OECD countries emitted 11,878 million metric tons. In 2030 the OECD countries will be responsible for 17,496 million metric tons of CO_2 emissions.

Stag-Hunt. The focus of their model is on the effects of different environmental instruments on the negotiation outcome. In contrast we do not distinguish between individual environmental instruments. We regard climate policy in general and not specific policies.

The remainder of the paper is organized as follows: In Section II., we distinguish between primary and - in the scientific literature widely neglected - ancillary benefits of climate policy. The concept of ancillary benefits is explained and circumscribed. Section III. provides an extensive survey of the literature on ancillary benefits. In Section IV. we depict international negotiations on climate change in a game-theoretic setting, where – in a first step - we consider exclusively primary benefits of climate policy. We discuss the influence of these benefits derived from the mitigation of climate change on the outcome of the international negotiations. Thereafter, in a second step, we integrate ancillary benefits into the game-theoretical setting. Due to the fact that the properties of ancillary benefits differ significantly from those of primary benefits, interesting consequences result from this integration of ancillary benefits. Finally, Section V. concludes.

II. Primary and Ancillary Benefits of Climate Policy

Additional to the primary benefits, climate policy regularly generates so-called ancillary or secondary benefits. These are benefits which result from climate policy but not from the induced climate protection. They are important in magnitude. Cost benefit analysis for the climate change problem should ideally incorporate ancillary benefits of climate policy (see Plambeck, Hope and Anderson 1997: 82).

Different climate policies have different effects and may initiate different individual actions reducing GHG concentrations. Consequently, although they all contribute to climate protection (and provide primary benefits), different policies imply different ancillary benefits.[2]

In order to illustrate the heterogeneity of ancillary benefits, the control of the most important greenhouse gas CO_2 is considered here.

Climate policies which are intended to reduce CO_2 concentrations initiate the sequestration of carbon by afforestation/reforestation and/or the reduction of CO_2 emissions. Yet, afforestation and reforestation do not only mitigate CO_2-induced global warming (and provide primary benefits) by sequestering carbon (C), these measures also increase the habitat for endangered species. Furthermore, forests can serve as recreational areas and reduce soil erosion. The conservation of tropical forests is of extraordinary importance since they house more than 50 per cent of global species of plants and animals (Sandler 1997: 91). Furthermore, Sandler and Sargent (1995: 160) point out that tropical forests provide a

[2] So stricter environmental regulations may afford benefits also to firms e.g. through improved product design, innovation, corporate morale and in other ways (see e.g. Porter 1991 as well as Heyes and Liston-Heyes 1999).

bequest value which the current generation derives from passing the forests on to future generations. Fearnside (2001: 180) stresses concerning the case of Brazil: “The environmental and social impacts of mitigation options such as large hydropower projects, mega-plantations or nuclear energy, contrast with the ‘ancillary’ benefits of forest maintenance.” An overview of studies assessing the co-effects of afforestation is provided by Elbakidze and McCarl (2007: 565).

Reduction of carbon dioxide emissions can be achieved by fuel combustion reductions, e.g. caused by the implementation of more efficient technologies or the reduction of road traffic, and the substitution of carbon-intensive fuels. Ancillary benefits induced by activities reducing carbon dioxide emissions accrue from the mitigation of non-CO_2 emissions, for example (see Figure 1). In fuel combustion processes CO_2 emissions are accompanied by emissions of, e.g., NO_X, SO_2, N_2O and others. Therefore, fuel combustion reductions do not only cause a decrease in CO_2 emissions but also diminish the emissions of other pollutants. In general positive health effects of air pollution reduction that accompany climate protection measures are considered to represent the most important category of secondary benefits.[3] Further negative impacts of air pollution like accelerated surface corrosion, weathering of materials and impaired visibility are mitigated by fuel combustion reductions, too. Road traffic mitigation does not only produce ancillary benefits by reducing the emission of air pollutants but it is also accompanied by lower noise levels and reduced frequency of accidents, less traffic congestion and less road surface damage.

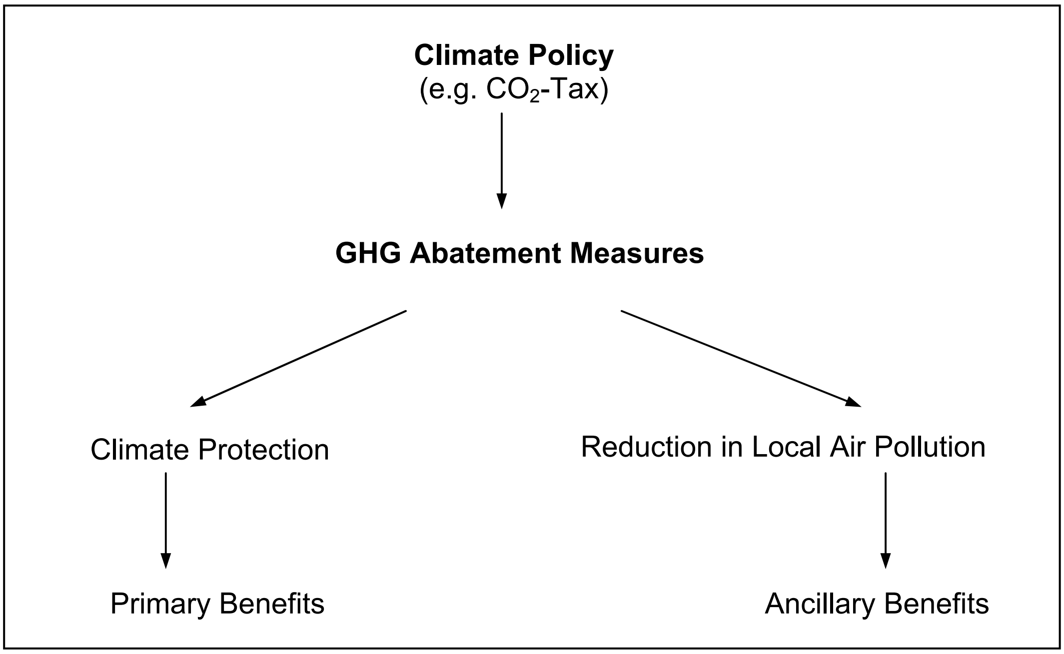

Figure 1: Climate Policy Generating Primary and Ancillary Benefits[4]

[3] Aunan et al. (2003: 289) annotate that “some particulate air pollution has a cooling effect on the atmosphere, reducing it may exacerbate global warming.”
[4] See Rübbelke (2002: 36).

Mostly, ancillary benefits are local or regional (IPCC 1996: 217; Pearce 1992: 5). They represent domestic public goods for individual countries. Local air pollution mitigation generated by climate policy, for example, can be exclusively enjoyed by the protecting country. Therefore, we can regard ancillary effects to be private to the host country of a climate policy. Consequently, they contrast to primary benefits which exhibit global publicness, i.e. no country can be excluded from enjoying primary benefits generated in any other country and there prevails non-rivalry concerning the consumption of the primary effect (climate stabilization) of climate policy.

Beyond the geographical distinction or distinction of the degree of publicness, primary and ancillary benefits can be distinguished concerning the delay between implementation of a climate policy and occurrence of benefits and the required scientific knowledge to assess the level of benefits (Rübbelke 2002: 22-23).

The intervals between the implementation of a GHG abatement measure and the occurrence of benefits differ significantly between primary and ancillary benefits. Primary benefits of GHG abatement arise with a delay of about 50 years. Secondary benefits on the other hand can largely be enjoyed almost immediately, since the avoided damages, e.g. from air pollution or noise, would have otherwise occurred instantly or shortly after the GHG emitting activity. Accordingly Ekins (1996b: 15) points out: “Unlike the benefits of reducing CO_2 emissions now in order to reduce damage from global warming in the future, reducing other emissions, which are causing damage now, yields benefits immediately.” If economists discount benefits with a positive rate, today's ancillary benefits get a higher weight compared with primary benefits in the distant future. The time lag between GHG abatement measures and the occurrence of primary benefits raises questions about the adequate discount rate.

Both groups of benefits also differ concerning the required scientific knowledge to assess the level of benefits. A prerequisite for forecasting primary benefits is an immense knowledge of processes in regional spheres and the whole global system. Since especially knowledge about processes in the global context is incomplete, uncertainties affect the assessment of primary benefits which exceed the ones associated with the assessment of ancillary benefits. Boyd, Krutilla and Viscusi (1995: 22) point out: “Although assessing environmental damages is not an easy task, it would seem substantially easier than assessing the impact of global warming damages”.

Of main importance in our subsequent analysis will be the distinction between both categories of benefits concerning their degree of publicness.

III. Survey of the Literature on Ancillary Benefits

In the beginning of the 1990s, economists started to assess the damage cost of climate change. The early assessments found for the mainly considered region, i.e. the US, that the damage cost will not be much higher than 1 percent of GNP in a scenario where CO_2 concentrations in the atmosphere double (see, e.g., Nordhaus 1991a,b; Cline 1992; Fankhauser 1992). Accordingly, the respective primary benefits of climate policy have been considered to be quite small.

Soon several economists criticized the early climate-policy benefit analyses. So, Ayres and Walter (1991) complained that Nordhaus (1991a,b) had omitted a very important category of benefits in his assessments, which were the ancillary benefits. Due to this omission, a major part of benefits derived from climate policy has been ignored.

The concern about the early climate-damage estimates has been shared by Pearce (1992), who demonstrated that the consideration of ancillary benefits would raise Nordhaus' highest marginal-damage estimate of US$ 66 per ton of carbon to over US$ 150 per ton of carbon.

During recent years, many economists seized the suggestions made by Ayres, Walter and Pearce, and directed their attention to the analysis of ancillary benefits. Several of these studies found out that secondary benefits even represent a multiple of primary benefits, as Pearce (2000: 523) illustrates in an overview.

Studies for Industrialized Countries

Conceptual frameworks for ancillary benefits have been provided by e.g. Krupnick, Burtraw and Markandya (2000) as well as Rübbelke (2002). Rübbelke (2003) analyses ancillary benefits in an analytical impure public good model and elaborates how ancillary benefits affect the level of climate policy while taking account of the application of different environmental technologies.[5] However, most studies on ancillary benefits are empirical ones and assess the levels of ancillary benefits.

Several European studies assessing ancillary benefits find high levels of these benefits. The European studies at hand are heterogeneous from a methodological as well as from a geographical point of view. They regularly consider individual countries and do not analyse the impacts of GHG control on the whole EU.[6] A couple of the early studies deal with Scandinavian countries.[7] Glomsrød, Vennemo and Johnsen (1992) analyse in the framework

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[5] Impure public good models have recently been applied in environmental economics also by Kotchen (2005). Within the framework of this kind of model he investigated environmentally friendly consumption.

[6] Capros et al. (1999) analyse the ancillary effects in the EU which arise in the shape of the mitigation of air pollution. RIVM et al. (2000) also consider ancillary benefits in the EU. They take account of air pollution mitigation. Data which consider ancillary effects concerning road traffic are also employed in this analysis (see first method, page 63).

[7] A discussion of studies analyzing ancillary benefits occurring in Nordic countries as well as in the UK is provided by Bye, Kverndokk and Rosendahl (2003).

of a computable general equilibrium model for Norway a carbon tax-induced CO_2-stabilization. They focus on the ancillary benefits associated with an air pollution decrease as well as a transport activity reduction. Benefits generated by reductions in transport activity accrue from a decline in road damage, noise, traffic accidents and congestion. In contrast Alfsen, Brendemoen and Glomsrød (1992) develop a macroeconomic model for Norway and also consider ancillary benefits derived from the mitigation of air pollution and road traffic. Håkonsen and Mathiesen (1997) refer to the externality cost estimates provided by Alfsen, Brendemoen and Glomsrød (1992) in their general equilibrium analysis. A different approach is chosen by Alfsen, Birkelund and Aaserud (1995), who determine ancillary benefits by assessing the reductions in the abatement costs required to meet the Sofia Protocol and the Helsinki Protocol brought about by an EC carbon/energy tax. They have a wider geographical scope than most of the other European studies by considering nine western European countries. However, they only focus on reductions in CO_2, SO_2 and NO_X emissions, and therefore omit ancillary benefits provided by the abatement of, e.g., other harmful pollutants like particulates or noise from traffic. Benefits associated with non-air-pollution related road traffic effects are also omitted by the study by Van Vuuren et al. (2006) analysing the ancillary benefits which are due to the implementation of the Kyoto Protocol. This study finds that the implementation of the Kyoto Protocol yields substantial ancillary benefits in Europe stemming from air pollution mitigation. The assessment takes account of the mitigation of the air pollutants SO_2, NO_X, PM_{10} and VOCs.

In contrast, Barker, Johnstone and O'Shea (1993) focus on measuring the importance of traffic-related benefits of a carbon/energy tax in the UK and omit the benefits of reduced air pollution. Barker, Johnstone and O'Shea (1993) show that although the traffic-related benefits (exclusive air pollution mitigation benefits) are assessed to be small in comparison to the ancillary benefits arising from less air pollution, they are not negligible.

Ancillary benefits for the UK are also assessed by Markandya and Rübbelke (2004). Their study focuses on the secondary benefits of mitigated air pollution and takes account of alternative technologies generating ancillary benefits independently of climate policy.

Some studies only analyse the physical impacts of climate policy on local and regional air pollution. Meyer et al. (1998, 1999) and Lutz (1998) simulate the effects of CO_2 tax and permit schemes on emissions of non-CO_2 pollutants for Germany, but do not translate these co-effects of climate policy into ancillary benefits. For their simulations they employ the econometric input-output model PANTA RHEI. The results show that there are important air quality improvements associated with CO_2 control policies in Germany. Löschel and Rübbelke (2005) assess the impact of alternative environmental technologies on the level of ancillary effects of climate policy in the shape of SO_2 emission reductions. Lutter and

Shogren (2001) show that the nature of ancillary benefits varies with the structure of the implemented climate policy.

Ayres and Walter (1991) were among the first analysts who compared European ancillary benefit assessments with estimates for the USA.[8] According to their results ancillary benefits in Germany are likely to exceed those in the USA. This may be due to the fact that the population density in Germany is higher than in the US. More recent estimates of ancillary benefits for 19 western European regions provided by Barker and Rosendahl (2000) also exceed the estimates found in studies for the USA, although the Barker/Rosendahl results are below the results found in earlier European studies. The view that population density matters for the importance of ancillary benefits is supported by Burtraw and Toman (1997: 22, 2000a: 10, 15, 2000b: 23) as well as Burtraw et al. (2003: 668-669), who compare several European and US assessment studies of ancillary benefits. Concerning the European literature their main focus is on a survey by Ekins (1996a). An overview of studies is also provided by Davis, Krupnick and McGlynn (2000).

Burtraw and Toman (1997: 21-22, 2000a: 15, 2000b: 23) as well as Burtraw et al. (2003: 669) stress that the discrepancies between the high European assessments and the US data may also result from geographic differences. A greater proportion of sulphur emissions in the eastern US is deposited off-shore rather than on-shore as in Europe, for example. Apart from the demographic and geographic arguments, the discrepancies between the US and European ancillary benefits assessments are probably attributable to several other factors, e.g. the more aggregate level of modelling in the European studies (Burtraw et al. 2003: 668; Burtraw and Toman 2000b: 23), high economic valuations of environmental impacts employed by the European researchers (Burtraw and Toman 2000a: 15; Morgenstern 2000: 7-8), and the application of a fixed coefficient procedure in European studies (e.g. Pearce 1992; Barker 1993) contained in Ekins' survey (Ekins 1996a).

Among the first analyses of ancillary benefits for the US is the study by Scheraga and Leary (1993). They examine ancillary benefits of energy taxes stabilizing the US emissions of CO_2. The analysis employs an intertemporal, general equilibrium model of the US economy and focused on health effects of the mitigation of several pollutants. It followed an assessment by Boyd, Krutilla and Viscusi (1995), which considered a different (and smaller) set of air pollutants than Scheraga and Leary (1993) did but took account of health as well as visibility effects of air quality improvement in the US. Another important study for the US is the one by Burtraw et al. (2003). The key pollutants they regard in their assessment are SO_2 and NO_X. As the overview by Pearce (2000: 523) shows, the analysis by Burtraw et al. (2003: 523) finds quite low ancillary benefit levels compared to other assessments. An overview of further US studies is provided by Burtraw et al. (2003: 666-667).

[8] Barker (1993) also assesses ancillary benefits for the US as well as for European countries (UK and Norway).

Joh et al. (2001) investigate ancillary benefits in Korea. They consider the benefits associated with the mitigation of PM_{10} and SO_2 effects were included in the assessment.

Studies for Transition and Developing Countries

Complainville and Martins (1994) consider emissions of CO_2, SO_X and NO_X in a multi-country, multi-sector, dynamic general equilibrium model (OECD GREEN). They find that air quality improvements may be as significant in developing countries as they are in industrialized countries.

Morgenstern (2000: 7) points out that the limited literature on ancillary benefits in developing countries even suggests that these are considerably higher than in the US. Studies investigating regions outside industrialized countries are provided, e.g., by Wang and Smith (1999a,b), Aunan et al. (2000, 2003, 2007), Garbaccio, Ho and Jorgenson (2000) as well as Vennemo et al. (2006) who analyse ancillary benefits in China. Van Vuuren et al. (2003) find that large co-benefits of climate protection by means of energy efficiency improvement prevail in China. However, the analysis by Gielen and Changhong (2001) for Shanghai shows that the relevance of no-regret options is limited because of significant energy efficiency improvements in Shanghai in recent years. Yet, they admit that Shanghai seems not to be representative for the whole of China and that main GHG emission mitigation potential may be located in the rural areas of China.

Dessus and O'Connor (2003) as well as Cifuentes et al. (2000) have a look at co-benefits of GHG control in Chile. An ancillary benefit analysis for India is provided by Bussolo and O'Connor (2001). Aaheim, Aunan and Seip (1997) as well as Aunan, Aaheim and Seip (2000) investigate ancillary benefits of energy saving in the eastern European transformation country Hungary. Markandya, Golub and Strukova (2003) provide an analysis of ancillary benefits in Russia.

Sagar (2005) points out that climate policy may also contribute immense social-economic benefits to the world's poor.

O'Connor (2000) provides a comparison of different ancillary benefit studies for developing countries. Rübbelke (2006b) investigates the role international transfers from industrialized to developing countries may play in international climate policy. In doing so, he takes account of ancillary benefits.[9]

The literature on ancillary benefits has grown immensely during recent years as can be observed from this survey. However, what is still largely lacking is the integration of ancillary benefits into the analysis of international negotiations on climate change. The only exception is a very specific model developed by Pittel and Rübbelke (2005). In the subsequent section

[9] For the effects of ancillary benefits in an international environmental matching agreement, see Rübbelke (2006a).

we will provide a more general formulation of their model and will work out the implications of the integration of ancillary effects.

IV. Negotiations on Climate Change

IV.1 An Analysis Including Exclusively Primary Benefits

Due to the public good properties of climate protection (non-rivalry in and non-excludability of consumption) there are free-rider incentives prevailing in international climate protection. Climate protection is the primary aim of climate policy and consequently, the derived benefits are called primary benefits of climate policy.

The free-rider incentives result in a suboptimal low world-wide provision of climate protection. Since there is no global coercive authority which may enforce international regulations to overcome the associated inefficiencies, voluntary negotiations among countries are considered the only reasonable means to address the global warming threat. The negotiation situation concerning the provision of public goods is in a game-theoretical setting regularly described in the shape of a Prisoner's Dilemma game. In such a game the dominant strategy of negotiators is not to agree on participation in an agreement on public good provision like the provision of climate protection. The situation can be illustrated by a bimatrix as the one depicted in Figure 2. It holds: $A_A^P > C_A^P$, $B_A^P > D_A^P$, $A_B^P > B_B^P$, $C_B^P > D_B^P$.

In the respective game setting the governments of two states A and B decide on whether they participate or do not participate in an international agreement on public good provision. The letters in front of the comas represent the payoffs for country A and the numbers behind the comas are the payoffs for country B, given their strategies "participation" and "no participation". As can be observed easily, each government will rigorously pursue the strategy "no participation" (or defection), regardless of the behaviour of its counterpart.

B's strategy / A's strategy	no participation	participation
no participation	A_A^P, A_B^P	B_A^P, B_B^P
Participation	C_A^P, C_B^P	D_A^P, D_B^P

Figure 2: Prisoner's Dilemma Game

Yet, the set-up of the prisoner dilemma game neglects an important aspect of international negotiations on climate change: the risk of a catastrophic outcome in case of mutual ignorance regarding the global warming threat and mutual defection. This risk can, however, be integrated by slightly changing the relation between the payoff given unilateral participation and the payoff given mutual defection: Countries' payoffs associated with mutual defection are now considered to be lower than the payoffs associated with unilateral participation. Consequently, a defection strategy would not represent the dominant strategy.
Given this modified scenario, the behaviour of a decision-maker now depends on the opponents' behaviour and the negotiation situation is characterised by a so-called Chicken game. The game, which belongs to the group of coordination games, deviates only slightly from the Prisoner's Dilemma game, but describes international negotiations on climate change more appropriately as already noted by Carraro and Siniscalco (1993).
Consideration of the risk of a catastrophic outcome modifies the pay-offs of countries A and B such that $A_A^C < C_A^C$, $B_A^C > D_A^C$, $A_B^C < B_B^C$, $C_B^C > D_B^C$ (Figure 3). It is still assumed that the climate catastrophe can be best prevented jointly by all countries. However, if other countries do not cooperate in international climate protection efforts, unilateral action would be the best response, since only such unilateral action can prevent complete inactivity in the combat of climate change and, therefore, the consequences of a catastrophic global warming outcome. Yet, any government hopes that the other countries participate in international climate protection, so that they themselves may take an easy ride. Then, they could save the expenses for own climate protection efforts and are nevertheless – due to the other agents' protection activities – saved from the climate change catastrophe.

B's strategy / A's strategy	no participation	participation	
no participation	A_A^C, A_B^C	B_A^C, B_B^C	$1\text{-}p_A$
participation	C_A^C, C_B^C	D_A^C, D_B^C	p_A
	$1\text{-}p_B$	p_B	

Figure 3: Chicken Game

In the depicted coordination game there exist no dominant strategies. Nevertheless, multiple Nash equilibria prevail which are associated with pure and mixed strategies. The Nash equilibria given pure strategies yield the payoffs (B_A^C, B_B^C) and (C_A^C, C_B^C). Provided there are uncertainties regarding the participation of other countries like the ones which prevailed for a long time concerning the ratification of the Kyoto Protocol by Russia, mixed strategies become relevant. In this case decision-makers estimate probabilities concerning the counterparts' behaviour. Country A estimates the likelihood with which country B will participate (p_B) or not participate (1- p_B) – and vice versa for country B (p_A and 1- p_A).

In order to determine the mixed strategies in the game in Figure 3, we have to calculate the likelihood p_B* (resp. p_A*) of participation by country B (country A), which makes the decision-maker in A (decision-maker in B) indifferent between playing "participation" and "no participation".

Probability p_B* is determined by calculating the level of p_B, where the expected payoffs of both strategies of A ("participation" and "no participation") coincide. This is the case if

$$C_A^C(1-p_B{*})+D_A^C p_B{*}=A_A^C(1-p_B{*})+B_A^C p_B{*}\,. \qquad (1)$$

The left-hand side represents A's expected payoff from participation and the right-hand side reflects A's expected payoff from defection. The mixed-strategy equilibrium requires:

$$p_B{*}=\left(1+\frac{B_A^C-D_A^C}{C_A^C-A_A^C}\right)^{-1}. \qquad (2)$$

Given our assumptions about pay-offs this expression is always smaller than unity and the numerator and denominator of $(B_A^C-D_A^C)/(C_A^C-A_A^C)$ are both positive. The term in the denominator of (2) gives the payoff increase country A receives when it decides to engage unilaterally in climate protection compared to its payoff in the case of mutual defection. The term in the numerator reflects the increase in country A's payoff when it decides to defect although country B engages in climate protection.

(2) shows that p_B^* is the higher, the higher country A's gain from unilateral action is compared to its loss from participating in a bilateral agreement. Given a high relative gain from participation, country A would decide to participate in an agreement even if it is relatively likely that country B also participates.

Analogously we get

$$p_A{*}=\left(1+\frac{C_B^C-D_B^C}{B_B^C-A_B^C}\right)^{-1}, \qquad (3)$$

with the interpretation of (3) following the same lines as the interpretation of (2).

If the decision-maker in A (in B) is not sure whether his counterpart participates or defects, then he should play "participation" provided he expects that B (A) participates with a probability which is below p_B^* (below p_A^*). Whether or not p_A^* is below or above p_B^* depends crucially on the type of countries considered and their respective pay-offs.

Let us again focus on the case of negotiations between industrialized and developing countries. Assume that country A is an industrialized country like Germany while country B is a developing country like China or India. The individual countries may also represent a group of countries, i.e. the whole group of industrialized countries or developing countries. It is regularly argued that climate change is in developing countries not as highly ranked on the political agenda as in industrialized countries, although by cost-benefit analyses negative consequences of climate change are especially forecasted for developing regions. Since the rank on the political agenda is crucial for decision-makers, the payoffs in the subsequent payoff matrices are set in a way that reflects the perception of the global warming threat in the political sphere of the respective countries.

Consequently, the decision-makers' perception of the level of the benefits from climate protection and not the level of the benefits themselves play the crucial role in our game-theoretical description of international negotiations. Accordingly, the payoffs for industrialized countries in Figure 3 are supposed to be lower in the case of missing climate protection activities than for developing countries. In contrast, the payoffs for industrialized countries are assumed to be higher than in developing countries if at least one country participates in climate protection. On the one hand, by decision-makers in industrialized countries a lack of international climate protection would be more intensely perceived as threatening than by governments in developing countries. On the other hand, climate protection is more positively perceived by decision-makers in industrialized countries than by their counterparts in developing countries. Therefore we suppose regarding the numbers in Figure 3: $A_A^C < A_B^C$, $B_A^C > C_B^C$, $C_A^C > B_B^C$, $D_A^C > D_B^C$.

In the Prisoner's dilemma game, this additional specification of the pay-off relation between industrialized and developing countries would have no effect on the outcome. In the Chicken game, however, it allows us to draw more concrete conclusions about the likelihood that countries do or do not participate.

Using equation (2) and (3) we can derive the following condition on the likelihood of participation of country A and B:

$$p_B^* >,=,< p_A^* \qquad \Leftrightarrow \qquad \frac{C_B^C - D_B^C}{B_B^C - A_B^C} >,=,< \frac{B_A^C - D_A^C}{C_A^C - A_A^C}. \qquad (4)$$

The ratios in the RHS expression of (4) are already known from (2) and (3). (4) shows that the likelihood with which countries participate depends crucially on their relative gains from participation. If, e.g., country B's relative gain is higher than country A's, it will participate in an agreement even if the probability of A to participate might be higher than its own.

Recall that we assumed that with respect to their respective perception industrialized countries (A), stand to lose more than developing countries (B) in the case of mutual defection compared to unilateral participation ($C_A^C - A_A^C > B_B^C - A_B^C$) , i.e. the denominator of the RHS term in (4) exceeds the denominator of the LHS term. With respect to the numerators, our assumptions allow for the numerator on the RHS to be larger, equal or smaller than the numerator on the LHS. Let us assume first that the losses from participating in a mutual agreement would be the same or less in industrialized compared to developing countries ($B_A^C - D_A^C \leq C_B^C - D_B^C$), then $p_B* > p_A*$ would hold. In this case the relative gain from participation of the industrialized countries would always exceed the relative gain of the developing countries. Consequently, participation of the developing country B in the climate change agreement would be less likely than the participation by the industrialized country A: The developing country will only cooperate as long as his supposed probability that the industrialized country participates does not exceed p_A*.

If $B_A^C - D_A^C > C_B^C - D_B^C$ holds, however, this might imply $p_B* < p_A*$. In this case, the loss in payoff from a shift from unilateral defection to mutual cooperation in the industrialized country exceeds the respective loss in the developing country by so much that the relative gain from participation becomes lower in the industrialized than in the developing country. Whether or not this assumption is sensible or not, remains open to debate. Given our line of argument above, it would seem straightforward to assume that not only, $C_A^C - A_A^C > B_B^C - A_B^C$, but also $B_A^C - D_A^C > C_B^C - D_B^C$. Yet, whether these higher absolute gains also translate into higher relative gains, is hard to tell.

The Stern Review (Stern 2007) and the 2007 IPCC Assessment Report (IPCC 2007) suggest that the consequences of climate change may have been underestimated in the past. The risk of possibly catastrophic outcomes may increase the estimated primary benefits of climate policy significantly. Application of such possible new insights to our depiction in Figure 3 would require modifications in the individual payoffs. The payoffs A_A^C and A_B^C would decline if new scientific insights suggest that climate change will have worse consequences than expected before. All other payoffs would increase. Therefore, the denominator of $(B_A^C - D_A^C)/(C_A^C - A_A^C)$ in (2) will increase which ceteris paribus induces an increase in p_B* as a country loses more in the case of mutual defection. With respect to the numerator, it can increase or decrease, depending on whether B_A^C or D_A^C increases more. The overall effect of a rise in the primary benefit estimate is, therefore, ambiguous and it is not clear whether it will cause the likelihood of participation in an international agreement on climate change to rise.

A similar reasoning applies to country B.

IV.2 Integration of Ancillary Benefits into the Analysis

Let us integrate secondary benefits (S_A and S_B) in our Chicken game setting next. We take account of the fact that ancillary benefits can be enjoyed exclusively by countries taking action in climate protection (see Figure 4). Please note also that the amount of ancillary benefits that arises is assumed to be independent of whether or not the other country participates in an agreement. This assumption seems straightforward as ancillary benefits arise solely locally and due to local policies.[10]

A's strategy \ B's strategy	no participation	participation	
no participation	A_A^C, A_B^C	$B_A^C, B_B^C + S_B$	1- p_A
participation	$C_A^C + S_A, C_B^C$	$D_A^C + S_A, D_B^C + S_B$	p_A
	1-p_B	p_B	

Figure 4: Chicken Game and Ancillary Benefits

Analogously to the procedure in the previous section, we can now determine the mixed strategies in the presence of ancillary benefits. Equalization of expected pay-offs under participation and defection in country A gives a modified version of equation (1):

$$(C_A^C + S_A)(1 - p_B{}^*) + (D_A^C + S_A)p_B{}^* = A_A^C(1 - p_B{}^*) + B_A^C p_B{}^* \tag{5}$$

from which we obtain:

$$p_B{}^{**} = \frac{A_A^C - C_A^C - S_A}{A_A^C - B_A^C - C_A^C + D_A^C}\,. \tag{6}$$

Analogously we get

$$p_A{}^{**} = \frac{A_B^C - B_B^C - S_B}{A_B^C - B_B^C - C_B^C + D_B^C}\,. \tag{7}$$

If the decision-maker in the industrialized country A (developing country B) is uncertain whether the other country plays cooperatively or not, then he should participate in the

[10] Changes in ancillary benefits due to different climatic conditions are assumed to be negligible.

international agreement, provided he expects country B (A) to play cooperatively with a likelihood which is below p_B** (below p_A**).

Comparing the results with the results obtained in Section IV.1, we find that the likelihood of participation of the individual countries in the international agreement rises. It holds that:

$$p_B{**} = p_B{*} + \frac{S_A}{B_A^C + C_A^C - A_A^C - D_A^C} > p_B{*} \tag{8}$$

and

$$p_A{**} = p_A{*} + \frac{S_B}{B_B^C + C_B^C - A_B^C - D_B^C} > p_A{*}. \tag{9}$$

Therefore, if the decision-maker in A (in B) is uncertain about his counterpart's behaviour, he should play cooperatively even if he would expect country B (country A) to participate with a likelihood exceeding p_B* (exceeding p_A*), as long as this likelihood does not exceed p_B** (does not exceed p_A**).

Studies on ancillary benefits suggest that these benefits are higher in developing countries than in the industrialized world. Furthermore, while an intensifying focus in developing countries lies on local and regional environmental problems, the threat of climate change has no priority on the political agenda of these countries (Aunan et al. 2000). Therefore, not only cost-benefit analyses assign higher secondary benefits to developing regions but it is also reasonable to assume that these benefits play a more important role in the political perception of developing than of industrialized countries. As Gielen and Changhong (2001: 258) point out for countries such as China: "In reality, however, the order of issues on the policy agenda is different. First the apparent local air pollution problems are tackled; next the more distant GHG problem is considered."

Halsnæs and Olhoff (2005: 2324) stress that "the inclusion of local benefits in developing countries in GHG emission reduction efforts will […] create stronger incentives for the countries to participate in international climate change policies." If we take account of these coherences and assume that $S_A > S_B$, then the likelihood of cooperative behaviour of developing countries rises relatively to the likelihood of industrialized countries.

V. Conclusions

In 2012 the Kyoto Protocol expires and a new climate protection agreement integrating commitments of developing countries is desired by the leaders of the majority of industrialized countries. The developing world, in turn, prefers to abstain from such commitments. The coordination of these opposing interests of industrialized and developing countries are and will be subject to international negotiations on climate change.

This paper demonstrates in a game-theoretical setting that the inclusion of ancillary benefits into the reasoning of decision-makers can strongly affect the outcome of such international negotiations. These ancillary effects are inherent in climate policy itself, since climate policy always generates secondary effects. Ancillary benefits can in general exclusively be enjoyed by the climate protecting country or region and are, therefore, benefits which are private for the respective country or region. Therefore, they contrast sharply to the primary benefits, which are benefits derived from the climate protecting impact of climate policy and are public to all. Since assessment studies estimate that ancillary benefits are important in magnitude, it is reasonable to conclude that their privatizing effect on the utility derived from protecting the climate tends to be significant. Nevertheless, this category of benefits has not been taken into account in an adequate way yet. This can be especially observed from the neglect of secondary benefits in analytical investigations of international negotiations on climate change. So far, researchers mainly focused on the empirical investigation of the level of those benefits. The implications of this important category of benefits can, however, be far reaching.

The integration of ancillary benefits does – on the one hand – raise the total benefits obtainable from a climate agreement. However, as our analysis of rising primary benefits – which are public to all countries – shows, a growing benefit level as such will not necessarily increase the likelihood of participation in an international agreement. Yet, the specific characteristic of ancillary benefits which only arises in the case of participation, induces indeed a positive impact on the probability of attending an international climate protocol. Furthermore, as we illustrate, this effect is likely to be especially strong in the case of developing countries.

However, the idea that private benefits provide incentives for developing countries to participate in international greenhouse gas abatement efforts is not new. One way of inducing such private benefits is to transfer technology or money from the industrialized to the developing world. Furthermore, issue linkage, i.e. the linkage of negotiations on a climate protection agreement with negotiations concerning club goods, may generate participation incentives. The option of attendance to a trade agreement, for example, can explicitly be made conditional on signing a climate protection protocol. Therefore, countries that participate in the international combat against global warming could also enjoy the merits of the club good “trade agreement”. Countries not participating in climate protection are excluded from the benefits that the trade agreement provides. Therefore, additional benefits of climate protection activities are generated by means of issue linkage or transfers and these benefits are private to the group of participants, while climate protection benefits represent a global public good. The privatizing effects of the additional benefits raise the attractiveness of participation in international environmental protection efforts and mitigate incentives to take a free ride. However, such privatizing effects are already inherent in climate policy itself, since climate policy regularly generates ancillary benefits, which are in general exclusively enjoyed by the climate protecting country of region. Yet, this is regularly ignored.

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