International Cooperation to Resolve International Pollution Problems

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Summary

This article provides a non-technical overview of important results of the game theoretical literature on the formation and stability of international environmental agreements (IEAs) on transboundary pollution control. It starts out by sketching features of first and second best solutions to the problem of transboundary pollution. It then argues that most actual IEAs can be considered at best as third best solutions. Therefore, three questions are raised: 1) Why is there a difference between actual IEAs and first and second best solutions? 2) Which factors determine this difference? 3) Which measures can help to narrow this difference? This article attempts to answer these questions after giving an informal introduction to coalition models.

Keywords: International pollution, International environmental agreements, Treaty design, Coalition theory

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Short contents list:

Glossary:

CBA: Abbreviation of cost-benefit analysis: a method, which uses abatement costs and benefits from abatement, in order to determine optimal (global) abatement levels as well as an optimal allocation of abatement burdens.

CEA: Abbreviation of cost-efficiency analysis: a method, which uses abatement costs, in order to determine an optimal allocation of abatement burdens for a given (global) abatement level.

C-Models: Abbreviation of compliance models. Coalition models that focus on compliance of signatories with the obligations of international environmental agreements.

Coalition Theory: Field in game theory that analysis the formation of coalitions. In the context of international environmental agreements coalition theory investigates which countries will accede to a treaty and whether they will comply with their treaty obligations.

Free Riding: Act of non-participation in an international environmental agreement (IEA) or non-compliance with treaty obligations agreed in an IEA.

Game Theory: Mathematical method that analyzes interactions of agents based on assumptions of the behavior of agents and predicting the outcome of those interactions. In the context of international environmental agreements, game theory investigates under which conditions cooperation between countries will be successful.

Effectiveness: Measures are called effective if they have a positive impact compared to some benchmark. The impact may be measured in ecological or welfare terms.

Efficiency: Also called cost-efficiency. Policy measures are called efficient if the achieve a target at minimal costs.

P-Models: Abbreviation of participation models. Coalition models that focus on participation in international environmental agreements.

1. Introduction

International pollution problems have become increasingly important issues on the agenda of politicians, economists and natural scientists. Prominent examples are the acidification of lakes and soils through sulfur and nitrogen oxides, the depletion of the ozone layer through chlorofluorocarbons (CFCs) and the rise of atmospheric temperature through so called greenhouse gases. A distinctive characteristic of international pollution problems is that pollution does not remain within national boundaries. Consequently, an optimal policy response would require that nations do not pursue a national but an *international environmental policy* where countries consider not only environmental damages at home but also those abroad caused by their emissions. This, however, requires *coordination* and *cooperation* among nations that is usually formalized in international environmental agreements (IEAs) of which those mentioned in the text are summarized in Table 1.

From a *theoretical point of view*, a *first best solution* to international pollution problems is straightforward and implies to conduct a *cost-benefit analysis* (CBA). In a first step *all* countries *emitting and suffering* from a pollutant have to be identified. In a second step information about abatement costs and benefits from abatement in the form of reduced damages have to be gathered. In a third step the optimal global abatement level and those of individual countries are determined by *maximizing the difference between aggregate benefits and aggregate costs from abatement*.

For the globally or socially optimal solution some general characteristics hold. *1) The higher aggregate benefits are compared to aggregate costs from global abatement, the higher is the globally optimal abatement level and vice versa. 2) Those countries with lower costs per unit of abatement (marginal abatement costs) should reduce pollution more than those with higher cost per unit of abatement. 3) If some countries face similar unit costs of abatement, then those countries that cause a higher environmental damage should abate more than countries which cause relatively lower environmental damage.*

The *first feature* guarantees that the choice of the global abatement level is based on rational principles. It recognizes that abatement reduces environmental damages but is also associated with costs in the form of forgone production and consumption of goods. In particular, it recognizes the following relations. On the one hand, costs increase more than proportionally with increasing levels of abatement. That is, at high levels of abatement, an additional unit of abatement involves higher unit costs (marginal abatement costs) than at lower levels since more sophisticated abatement devices have to be implemented. On the other hand, benefits increase less than proportionally with increasing abatement levels. That is, at high levels of abatement, an additional unit of abatement generates less additional benefits (marginal benefits) since environmental quality is already high.

The first feature implies for instance that global abatement should be higher for CFC-pollutants than for greenhouse gases. Both pollutants cause severe damages and therefore aggregate benefits as well as marginal benefits from abatement are high. However, abatement costs as well as marginal abatement costs of CFCs are relatively low compared to greenhouse gases since for CFCs cheap substitutes have been developed over recent years, whereas this option is currently not available for fossil fuels, the use of which causes greenhouse gases.

The *second feature* guarantees *cost-efficiency*. That is, abatement levels should be allocated to the various countries in such a way that the globally optimal abatement level is achieved at least cost.

This feature is particularly important if an ambitious abatement level is implemented in order to keep costs at moderate and acceptable levels. It implies for instance in the case of greenhouse gases that developing countries and countries in transition should shoulder a greater abatement burden than industrialized countries since - on average - they face lower unit abatement costs. The reason is that in most industrialized countries the level of environmental protection is already high and hence additional abatement efforts are associated with high abatement costs. In contrast, in countries like China and Russia, energy efficiency is very low. That is, emissions per gross national product are very high and hence these countries can conduct abatement at low unit costs.

The *third feature* guarantees *ecological efficiency*. It does not apply to global pollutants but only to *regional pollutants* where the distributional pattern of the deposition of emissions matters for global damages. For instance, Great Britain should reduce more sulfur emissions than other countries since most of its emissions are transported to Nordic countries with sensitive ecological systems where emissions cause much environmental damage. In contrast, *global pollutants*, like CFCs and greenhouse gases, mix uniformly in the atmosphere. Therefore, irrespective of which country reduces emissions, one unit of emission reduction generates the same global benefit.

The first and the third feature stress the *first-best-solution character* of the globally optimal solution: not only information about abatement costs but also about benefits from abatement is required to determine optimal abatement levels. If information about benefits from abatement is not available or uncertain, then a more pragmatic and *second best solution* to international pollution problems is to conduct a *cost-efficiency analysis* (CEA). In a first step only those countries emitting a pollutant have to be identified. In a second step only information on abatement costs has to be gathered. In a third step optimal individual abatement levels are determined by *minimizing aggregate costs from abatement* for a given global abatement target. For such a pragmatic solution the second characteristic from above applies, except that the global abatement target is set by a decision maker and may not be globally optimal. For instance, in the case of greenhouse gases the Kyoto Protocol targets at an emission reduction of 5.2 percent based on 1990 emission levels to be achieved in the period 2008-2012. Though this target has been set based on scientific evidence, it is certainly not globally optimal in the sense of a CBA but mainly reflects a political compromise between the signatories to this agreement. Since all countries emit greenhouse gases, a cost-efficient solution would also require - as in the case of a CBA - that all countries contribute to the achievement of this target and that - as mentioned above - developing countries and countries in transition contribute more to cost-efficient cooperation.

From a *practical point of view*, however, things are less straightforward. Already a casual analysis of international environmental agreements reveals that implemented solutions are usually neither first nor second best solutions, and can be regarded at best as third best solutions. This will be illustrated with some empirical evidence that I structure according to four features.

Participation

In most IEAs the number of parties falls short of the total number of countries involved in the externality problem. Here, "involved countries" means not only all countries in the full sense of a CBA (all countries that emit and suffer from a pollutant) but also just in the sense of CEA (all countries that emit a pollutant). This observation is particularly true for those IEAs with explicit and ambitious abatement targets. For instance, almost all countries emit and suffer from the global pollutants CFCs and greenhouse gases, which thus amounts to roughly 200 countries. However, only 38 industrialized countries have originally accepted greenhouse gas emission ceilings under

the Kyoto Protocol in 1997 and the US, as a major polluter, withdrew from the Protocol in spring 2001. Also only 26 countries signed the Montreal Protocol in 1987, regulating CFC emissions, though participation has risen substantially over recent years to presently 181 members. However, fewer countries participate in the amendment protocols, which followed the Montreal Protocol and which target at more ambitious abatement targets. For instance, the London Protocol signed in 1990 counts 153 participants, the Copenhagen Protocol signed in 1992 counts 128 participants, the Montreal Protocol signed in 1997 comprises 63 participants and the Beijing Protocol has been signed by 11 countries in 1999, though this last amendment protocol has not yet come into force since it has not been ratified by enough countries so far. Moreover, though sulfur is a major air pollutant that is emitted by and from which most countries suffer in Western and Eastern Europe and North America, the Helsinki Protocol signed in 1985 counts currently only 22 parties of which 16 are EU-countries. In contrast, participation in the framework conventions preceding the above-mentioned protocols, which are basically only declarations of concern about an environmental problem and declarations of intentions that pollution should be reduced without specific abatement obligations, is very high. For instance, the Framework Convention on Climate Change (FCCC) preceding the Kyoto Protocol counts 186 parties, the Vienna Convention preceding the Montreal Protocol and its successor protocols counts 182 parties and the Convention on Long-Range Transboundary Pollution (LRTAP) preceding the Helsinki Protocol counts 48 parties.

Compliance

There is ample evidence that even if countries participate in an IEA, they do not always comply with their abatement obligations. This applies not only to IEAs regulating pollutants but applies to IEAs in general and has been confirmed by many empirical studies on compliance conducted by political scientists. For instance, no less than over 300 infractions of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) signed in 1973 in Washington D.C. have been counted per year. Also, all important parties breached the International Convention for the Regulation of Whaling (ICRW), signed in 1946 in Washington D.C. Japan, Norway and the USSR are particularly smart since they catch whales under the guise of "scientific whaling" that is legal under the whaling convention. As a result, Norway hunted five times as many whales in 1997 as in 1992. IEAs regulating pollutants are no exception. For instance, even though important CFCs are banned under the Montreal Protocol since 1991, customs officers throughout the world regularly intercept deliveries of these substances.

Effectiveness

The few empirical studies measuring the effectiveness of IEAs suggest that implemented abatement levels are close to those which countries were to implement anyway if they would pursue their self-interest non-cooperatively (national environmental policy). This has been confirmed for instance for the above mentioned Montreal Protocol signed in 1987, the Helsinki Protocol signed in 1985 and the Kyoto Protocol signed in 1997 but also for the Oslo Protocol that has been signed in 1994, which is the successor protocol to the Helsinki Protocol on sulfur reduction. That is, agreed abatement targets, though they may seem large in absolute terms, are small when compared to those required by a globally optimal solution.

Efficiency

As long as countries have different unit abatement costs, cost-efficiency requires that countries reduce emissions to a different extent. In reality, however, uniform solutions are part of many IEAs. Under many "old" IEAs *uniform emission reduction quotas* have been negotiated, which imply that countries have to reduce their emissions by the same percentage compared to some base year. The

list of examples is long and includes the Helsinki Protocol, which suggested a 30 percent reduction of sulfur emissions from 1980 levels by 1993. Moreover, the "Protocol Concerning the Control of Emissions of Nitrogen Oxides or Their Transboundary Fluxes" signed in Sofia in 1988 called on countries to *uniformly* freeze their emissions at 1987 levels by 1995 and the "Protocol Concerning the Control of Emissions of Volatile Organic Compounds or Their Fluxes" signed in Geneva in 1991 required parties to reduce 1988 emissions by 30 percent by 1999. Only "modern" IEAs apply the "principle of different responsibilities", including the Oslo, Kyoto and Montreal Protocol. However, even though the Montreal Protocol allows developing countries to be exempted from certain regulations, to claim a transition period until full compliance is required and to draw on support from various financial mechanisms to meet their targets, it calls on uniform reductions of various CFC-pollutants in the different amendments. Also in the original draft of the Kyoto Protocol emission reduction of the major global players are very similar (USA: 7 percent, Japan and Canada: 6 percent and EU: 8 percent) despite unit abatement costs that differ widely.

In the light of the empirical evidence three questions arise:

1) *Why is there a difference between actual IEAs and first and second best solutions?*
2) *Which factors determine this difference?*
3) *Which measures can help to narrow this difference?*

The answer depends by and large on the field and method of the analysis. In this paper I survey the answers of the environmental economics literature using coalition theory - a field of game theory - to analyze the formation and stability of IEAs. Game theory is a mathematical method analyzing and predicting the outcome of the interaction of agents. Coalition theory focuses on the possibilities of forming stable agreements between agents in order to pursue a common goal. In the game theoretical literature on international pollution problems agents means countries or governments, a coalition is a group of cooperating countries that aims at reducing emissions beyond the non-cooperative status quo and hence *coalition theory is a method for analyzing the incentive structure of countries to participate in an IEA and to comply with the terms of the agreement*. So far, this literature abstracted from the political decision process within countries for simplicity and assumed that governments aim at maximizing the welfare of their citizens (see section 5 for a discussion of this assumption).

In what follows I provide in section 2 an informal sketch of the structure of coalition models and a preliminary answer to the first question raised above. Subsequently, I discuss important factors which influence the success of cooperation in section 3 and outline elements of treaty design that can hamper or encourage cooperation in section 4.

2. Coalition Models

2.1 Problems of Modeling Coalition Formation

Analyzing coalition formation is a complex business and involves three steps. First, the *decision about participation or membership* has to be modeled. The features of this decision are called the *rules of coalition formation*. Important rules are for instance the *sequence of coalition formation* (simultaneous versus sequential process), the *number of coalitions* that can form (single versus multiple coalitions), the *nature of membership* (open versus exclusive membership; that is, free versus restricted accession to a coalition) and the *degree of consensus* needed to form a coalition. (For details see section 4.) Second, the *decision about the design of an agreement* within a coalition

has to be modeled. Important ingredients are the implemented *global abatement level* within the coalition, the *allocation of the abatement burdens* on the coalition members, the *level and the donors and recipients of possible transfer payments*, the *type, level and the allocation of the obligations of sanctions* in case of non-compliance. Third, *what stability of a coalition means* has to be defined and stable coalition structures have to be determined.

The first and second step concerns the actual process of coalition formation. Ideally, this process should be modeled as an endogenous process that follows from the behavior of countries. However, in practice, it turned out that this approach is too ambitious. Therefore, all models make some simplifying assumption, which are plausible but exogenous, and solve for the remaining endogenous variables. Moreover, the various models capture some but not all aspects of coalition formation and concentrate on certain aspects. The third step relates to the prediction of the outcome of coalition formation and depends on the notion of an equilibrium concept. Though the various models differ in many aspects, they all share one *fundamental assumption: there is no third party like an international agency that can implement cooperation and hence the parties themselves must enforce treaties.* Thus, in contrast to the political science and juridical literature, the game theoretical literature considers international law as non-binding since the International Court of Justice can only open a trial if the accused party agrees. Consequently, a preliminary answer to the first question raised above is that *due to the lack of a central authority stability of first or second best solutions are difficult to obtain.* Generally, stability of an IEA depends on three conditions.

1) *Profitability*: Each participant in an IEA must receive more than in the non-cooperative status quo.
2) *Participation*: No participant has an incentive to leave an IEA to become non-signatory.
3) *Compliance*: No participant has an incentive to violate the terms of the agreement.

The first condition is a basic prerequisite for successful cooperation and may be seen as a nessary though not sufficient condition for participation and compliance. The second and third condition capture the phenomenon that even if an IEA is profitable to all participants, countries face two types of free-rider incentives. The *first type* is the incentive to remain a non-signatory, or in the more general context, to belong to a coalition that contributes less to abatement than other coalitions. The *second type* is the incentive to join an IEA but to violate its terms. In both cases, free-riders save abatement costs but benefit from abatement efforts of neighboring countries. Again, it turned out be too complex for game theoretists to construct a model that simultaneously captures all three stability conditions. Though all models capture profitability in some way, they focus either on participation or compliance. Therefore, coalition models can be divided into two groups: *participation models* (P-models) and *compliance models* (C-models)

From the discussion it is evident that there is no "universal model", which captures all aspects of coalition formation and stability. Consequently, there is also no universal answer to the three questions raised above and conclusions have to be drawn with caution. Nevertheless, in order to provide a concise summary of the main findings of the game theoretical literature on coalition formation, I avoid qualifications in the discussion in section 3 and 4 and refer the interested reader for details to the bibliography at the end of this article. However, in order to understand how the results in section 3 and 4 are derived and on which fundamental assumptions they are based, a brief sketch of the structure and features of coalition models is subsequently provided.

2.2 Structure and Features of Coalition Models

2.2.1 P-Models

P-models have a few things in common. First, they assume (except one model; see the bibliography) that if a coalition forms, coalition members maximize the aggregate welfare to their coalition but ignore the welfare of outsiders. This has two implications. a) There is cooperation among coalition members but some rivalry across coalitions. b) The *global abatement level of the coalition is optimal for the coalition* in the sense of a CBA and the *allocation of abatement burdens among its members is cost-efficient*, that is, it is optimal for the coalition in the sense of a CBA or CEA. Thus, if a P-model predicts that a coalition structure different from the grand coalition (the coalition comprising all countries) is stable, suboptimality stems not from a suboptimal design of a treaty but only from the fact that not all countries participate in an IEA. As a tendency, the larger a coalition, the higher will be the implemented abatement target. Thus, if single countries join a coalition (a cooperation of at least two countries) or if two coalitions merge, the global abatement level increases. By the same token, if countries leave a coalition or if coalitions break apart, global abatement will decrease. Thus, there are two benchmarks. At one end, if no country forms a coalition, that is countries remain singletons, they pursue their own national environmental policy, which is the non-cooperative status quo. At the other end, if all countries are in one coalition (grand coalition), they pursue an optimal international environmental policy by implementing globally optimal abatement levels. Hence, any coalition structure in between these two benchmarks is superior to the non-cooperative status quo but inferior to the globally optimal solution. The term coalition structure simply refers to the allocation of countries into groups. For instance, in the case of three countries there are five possible coalition structures: ({1},{2},{3}); ({1,2},{3}); ({1,3},{2}); ({1},{2,3}) and ({1,2,3}). The first coalition structure is the singleton coalition structure, representing the *non-cooperative status quo*; the second, third and fourth coalition structure comprise coalitions of two countries, representing *"partially cooperative solutions"*; and the last coalition structure is the grand coalition, representing the globally optimal or *"fully cooperative solution"*.

Second, P-models assume that once countries have decided on their membership they will comply with their abatement and transfer obligations. Therefore, the free-rider problems of real IEAs (non-compliance) are underestimated. Third, a particular coalition structure (state 1) is called stable if countries have no incentive to move to another coalition structure (states 2, 3,...). Since countries can always remain singletons because of voluntary participation, a minimum condition for stability is profitability.

2.2.2 C-Models

C-models also have features in common. First, they put less emphasis on the actual process of coalition formation but focus on whether and how a treaty can be enforced. Stability is checked for the grand coalition implementing globally optimal abatement levels but also for suboptimal designs of treaties, comprising smaller coalitions, less ambitious abatement targets and an inefficient allocation of abatement burdens. Second, they assume that a group of countries agrees on the terms of an IEA in stage 1, which have to be enforced in subsequent stages 2, 3, ... by their members. Since IEAs typically do not specify the end of a treaty, C-models assume an infinite time horizon. A treaty is called stable, that is, all coalition members comply with their obligations, if the discounted payoff from cooperation is larger than the discounted payoff from taking a free-ride and subsequently being punished. Consequently, a necessary condition for stability is profitability since

otherwise it is never possible to deter non-compliance via sanctions. Third, C-models emphasize the role of sanctions for stability. On the one hand, the harsher sanctions are, the easier it is to sustain cooperation. On the other hand, sanctions have to be credible to deter non-compliance. Credibility means two things in particular. a) Sanctions must provide a treaty violator with an incentive to go along with the punishment so that all parties can return to "normal terms" as quickly as possible. Consequently, sanctions must be moderate so that the punisher finds it more attractive to "cooperate" during his punishment than to leave the treaty. b) Sanctions must be designed such that those countries conducting the punishment suffer no disadvantage. That is, there should be no room for a treaty violator to offer his potential punishers a deal to treat bygones as bygones, promising to resume cooperation. Such kind of *renegotiation* would imply that the threat of punishment would loose its credibility in the first place and stability of an IEA would suffer. Again, only moderate sanctions will satisfy this condition. Sanctions satisfying condition a and b are called *renegotiation-proof*.

3. Factors Influencing the Success of Cooperation

3.1 Degree of Asymmetry

Though cooperation raises global welfare, individual countries may be worse off than in the status quo. That is, cooperation is not always profitable for all countries. This may be true for optimal solutions in the sense of a CBA but also in the sense of a CEA if countries have heterogeneous preference for the environment and/or different abatement costs. The reason is simple. If those countries which contribute on average more to cooperation are also those countries which benefit less on average from cooperation, profitability may be violated. As illustrated in the Introduction, a CBA and CEA requires those countries that face lower unit abatement costs than other countries (e.g., developing countries like Somalia and Ecuador and countries in transition like Russia and China in the case of greenhouse gases) and those countries that cause more regional damages than other countries (e.g., Great Britain in the case of sulfur) to contribute more to cooperation. As argued below, these are also countries that will enjoy low benefits from cooperation where low benefits from abatement may be due to various reasons. First, a country or its citizens have lower environmental preferences than other countries, even though the objective environmental damage caused by pollution may be similar. For instance, due to their lower stage of economic development, it is not surprising that developing countries usually put less weight on environmental quality but a higher weight on economic growth. Second, a country is less affected by pollution than other countries due to its endowment with natural resources. For instance, some studies in the context of the greenhouse gas effect come to the conclusion that Russia may even benefit from global warming since some currently non-arable land may then be used for agricultural production due to more favorable climate conditions. Third, a country is less affected by pollution because of its geographical location. For instance, Great Britain suffers less from acid rain since a large part of its sulfur emissions are transported to the European continent, particularly to the Nordic countries.

It is evident that even if asymmetries are not that strong that profitability is violated, they nevertheless pose a problem for participation and compliance. Those countries which benefit on average less than other countries from cooperation have a strong incentive either to remain a non-signatory or to violate the terms of the agreement.

From a global perspective the finding may be called a *paradox*. On the one hand, the larger asymmetries of unit abatement costs are, the larger are the gains from a cost-efficient allocation of abatement burdens compared to a uniform and inefficient allocation. On the other hand, the larger

asymmetries of unit abatement costs are, the larger will be the asymmetries from the gains from cost-efficient cooperation and the more likely it is that stability of an IEA will be violated.

Generally, there are two measures to balance asymmetries. First, those countries which gain more on average compensate those countries which gain less on average or which loose from cooperation. Second, abatement burdens are allocated such that the critical countries have to contribute less to cooperation. However, as will be argued in section 4, both measures provide no straightforward solution and are associated with some disadvantages. Compensations themselves suffer from free-rider problems and an allocation of abatement burdens different from the rules of a CBA or CEA implies a loss of global welfare.

3.2 Number of Countries Suffering from Pollution

The higher the number of countries affected by pollution, the higher are free-rider incentives. The reason is that the more countries suffer from pollution, the smaller is the effect of an individual country on environmental quality. On the one hand, if a signatory free-rides, environmental quality will deteriorate only marginally. On the other hand, if a non-signatory contributed to cooperation via participation in and compliance with an IEA, environmental quality would only improve marginally. This finding has also been called a *paradox* in the literature since it can be shown that cooperation is particularly important from a global point of view if many countries suffer from transboundary pollution. The reason is simple: the more countries suffer from pollution the higher is the degree of externality across countries if countries behave non-cooperatively and hence the higher are the global gains from cooperation.

The theoretical result suggests that the reduction of greenhouse gases would bring about large welfare gains due to the global character of this pollutant. However, it also explains why it has proved so difficult to establish cooperation under the Kyoto Protocol: only 38 countries signed the protocol, the US withdrew from the treaty, the protocol has not been ratified and therefore it did not go into force by the time this article was written in June 2002 and global abatement amounts only to 5.2 percent compared to 1990 emission levels.

3.3 Benefit-Cost Ratio from Abatement

The higher the benefit-cost ratio from abatement, the higher are free-rider incentives. The reason is that the higher the benefit-cost ratio, the higher will be the implemented global abatement target within a coalition and individual contributions of signatories. A high abatement target implies for a signatory, which complies with treaty obligations, high unit abatement costs. Consequently, free-riding is particularly attractive under these conditions since abatement costs drop substantially but benefits only marginally. A similar argument applies to non-signatories. Joining a coalition would be associated with high additional abatement costs but the effect on environmental quality at the margin is only small.

In terms of free-rider incentive of type 1 (see section 2.1), a high benefit-cost ratio implies either that only few countries join an IEA or it implies that many countries sign an IEA but that the cooperative global abatement level implemented by the coalition only marginally exceeds that in the non-cooperative status quo. In terms of free-rider incentive of type 2 (see section 2.1), a high benefit-cost ratio implies that either only few signatories comply with their abatement obligations or many signatories comply but then abatement obligation will be very moderate and close to non-cooperative levels.

This result has also been called a paradox in the literature since the higher the benefit-cost ratio, the larger are the gains from cooperation. This is due to a simple economic relation (see the first characteristic of a CBA in the Introduction). If costs are relatively high compared to benefits from abatement, then also a socially optimal solution would call only for moderate emission reductions. Hence, also the difference between a socially optimal solution and the non-cooperative status quo is small. This is different if the benefit-cost ratio is high. Then high abatement efforts would be advisable from a global point of view and hence it would be particularly unfortunate if countries remain close to the status quo.

The theoretical result suggests that success of an IEA cannot be inferred from the number of signatories. Moreover, the Montreal Protocol may be less successful than the Kyoto Protocol in the long run. Though the Montreal Protocol counts more signatories than the Kyoto Protocol, overall abatement may come closer to what is required by a CBA and compliance may be higher under the latter than under the former protocol.

3.4 Leakage Effects

The term leakage effect describes the phenomenon that if coalition members increase their abatement efforts compared to the status quo, outsiders may reduce their abatement efforts. Though this counter reaction does usually not completely offset the efforts of signatories, it negatively affects the success of cooperation. Leakage effects are an implication of the fact that in the presence of transboundary pollution, abatement is a public good from which no country can be excluded. Thus, also non-signatories benefit from higher abatement efforts of signatories via lower environmental damages. Consequently, non-signatories pursuing only a national environmental policy feel less environmental pressure and adjust their abatement level downward. In some cases, this downward adjustment is also encouraged by market effects. For instance, consider the market for crude oil. If environmentally conscious countries (signatories) pursue an energy-saving policy, the demand for oil will drop and so will prices. Consequently, the use of oil by less environmentally conscious countries (non-signatories) increases, which at least partially contradicts the energy saving policy by signatories.

It is evident that the larger leakage effects are, the less successful will be cooperation, where the extent of leakage effects depends on a number of factors. First, as the example suggests, the higher the sensitivity of prices for environmentally damaging products, the higher will be leakage effects. Second, the larger the benefit-cost ratio from abatement of non-signatories, the larger will be leakage effects. Again, this may seem paradoxical but a high benefit-cost ratio implies that abatement efforts of signatories have a large impact on non-signatories via a reduction of environmental damages. Consequently, a downward adjustment of abatement efforts is particularly encouraged. In terms of a comparison between CFCs and greenhouse gases this result suggests that leakage effects will be more important in the case of CFCs than in the case of greenhouse gases. Third, the more countries remain outside an IEA, the larger will be leakage effects. Thus, despite the fact that more signatories may suggest that it is more difficult to agree on ambitious and efficient abatement targets, enlarging a coalition may be a sensible strategy if expected leakage effects are large. Consequently, the effort of industrialized nations under the Montreal Protocol to provide many incentives for developing countries to join this protocol seems to have been a clever strategy in retrospect. In contrast, the result questions the threat of the US to withdraw from the Kyoto Protocol if developing countries would not also join this agreement because of the fear of

leakage effects. However, taking a long term view their fear may turn out to be not totally unwarranted since it is expected that important developing countries like India and China will experience much growth in the future associated with large amounts of greenhouse gas emissions.

3.5 Economies of Scale Effects

An important reason for suboptimal IEAs is that free-rider incentives increase with increasing abatement levels. As argued above, the reason is that with increasing abatement activities, unit abatement costs increase more than proportionally, whereas unit benefits from abatement increase less than proportionally. However, suppose unit costs drop with increasing abatement levels, at least in some range, due to economies of scale. This could happen for instance if countries coordinate not only their environmental policy but also their research and development (R&D) activities. If countries work together to develop clean technologies and share their knowledge, unit abatement costs can be reduced. This is particularly true for research activities involving high fixed costs, which can then be shared by more countries through cooperation. For instance, the Kyoto Protocol and the Montreal Protocol have a provision in their treaties that aims at the exchange of technological know-how between industrialized and developing countries. Also the joint implementation of environmental policy measures may generate economies of scale effects. For instance, some years ago, the European Commission launched a law that required the installation of catalytic converters in all cars sold throughout the EU. The uniform implementation of this law implied that the market for unleaded petrol and cars with catalytic converters was no niche but a large market, which reduced costs of switching to the new technology.

Scaling effects have two important implications. First, only if enough countries sign an IEA, scaling effects will materialize and cooperation will be profitable. The size of this "minimum critical coalition" will increase with fixed costs of establishing cooperation on R&D. Second, if the critical size is reached, then scaling effects may allow to expand a coalition. This is at least true in some range, until diseconomies of scale effects, due to high transaction cost of coordinating environmental policy, stemming from too much bureaucracy, become too strong. Thus, in order to reap scaling effects, it is important to make sure that the minimum critical coalition forms. However, as long as countries are unsure whether enough countries will accede to an IEA, they will be careful in putting their signature under a treaty. Therefore, many IEAs have established a minimum participation clause which basically says that only if a certain number of countries have signed an IEA, the treaty will go into force and will be binding for all signatories. For instance, the Kyoto Protocol can only enter into force after signatories responsible for 55 percent of emissions of the original signatories of this treaty have ratified the Protocol.

3.6 Planning Horizon and Discounting

The longer the planning horizon, the more governments think ahead when deciding on their environmental policy. The less governments discount time, the more weight receive future compared to current events. For most international pollution problems it turns out that the longer the planning horizon and the less countries discount time, the more successful will be cooperation. The reason is the following. First, most international pollutants are stock pollutants which persist for a long time in the environmental systems. This is particularly true for global pollutants like greenhouse gases which remain in the atmosphere for more than 50 years until they disappear due to the natural rate of decay. Thus, abatement efforts taken today have an immediate impact on abatement costs but have only a positive impact on climate in the far future. Thus, if governments are myopic and/or discount time much, they do not realize benefits from abatement and will

therefore not join an IEA. Second, non-compliance with treaty obligations provides a country with a temporary free-rider gain. Consequently, if countries are myopic and/or discount time much, they value this temporary gain more than the long term gains from cooperation despite the subsequent punishment.

In practice, it seems that short-term planning and high discounting pose a problem for solving international pollution problems. In most democracies politicians strive for reelection, and, given that politicians are usually only elected for 4 or 5 years, they very much depend on short-term success. Thus, particularly, previous to elections, discounting will be high and long-term planning will play a minor role, jeopardizing the success of IEAs. Therefore, one could think of transferring national enforcement from the government to the bureaucracy, which, by nature, is less dependent on election cycles. A further measure could be to transform international obligations of an IEA into national law as this is mentioned in some IEAs. For instance, the Waigani Convention has a provision that requires implementing abatement duties into national law. Since interference with the judiciary involves high political costs in most democracies, opportunistic behavior of governments could be limited by such a measure.
Moreover, it has been claimed that there is an inverse relationship between the wealth of nations and the discounting of time. Following this claim, fostering economic development in developing countries would lead these governments to discount time less and the prospects for cooperation would be brighter. Such a strategy is pursued under some modern IEAs. For instance, the parties to the Montreal Protocol established the so called "Multilateral Fund" which aims at transfering environmentally friendly technologies to developing countries under "fair conditions". Transfer projects include replacement of CFC-based foam blowing machinery with new non-CFC equipment.
Finally, discounting also depends on the uncertainty of future events. Therefore, investment in research about the effect of global warming and the expected abatement costs may be a measure to reduce uncertainty and hence the discounting of time. For instance, the Framework Convention on Climate Change has a provision requiring member states to conduct research on the effects of global warming. However, as long as the extent of research remains unspecified, obligations cannot be enforced. Moreover, in some cases it could be argued that pointing out that more research is needed before actions can be taken is only an excuse for delaying the implementation of serious abatement measures.

3.7 Reputation Effects

Reputation means either that signatories receive an additional gain from cooperation just from the fact that they belong to the "group of good guys" or that non-signatories receive some disutility because they belong to the "group of bad guys". Thus, reputation is also associated with the notion of fairness and political correctness. It can be shown that the larger the reputation effect is, the larger will be the number of signatories and the more successful is cooperation.

From a theoretical point of view, this result is hardly surprising. In fact, assuming enough sense of fairness, any problem of cooperation can trivially be solved. From a practical point of view, the result may be more interesting. Reputation effects may be encouraged through governmental and non-governmental institutions that regularly publish the members of an IEA, their abatement obligations, their compliance records and the overall success of an IEA in terms of achieving ecological targets. Thereby, environmental issues and the performance of individual countries

become more transparent to the public, which may increase the pressure on governments to behave environmentally friendly.

4. Issues of Treaty Design Influencing the Success of Cooperation

4.1 Membership Rules: open versus exclusive membership

Open membership implies that any country, which wants to join an agreement, can become a signatory to an IEA. In contrast, *exclusive membership* means that accession is only possible by the consent of present members. Empirical evidence suggests that almost all protocols of major past IEAs allow for unrestricted accessions of new members. From a theoretical point of view, things look different, though at first thought one would expect that the membership rule should make no difference: abatement constitutes a public good and therefore signatories of an IEA should always welcome new coalition members. At second thought, however, it is evident that additional members may also be associated with negative effects, which can be avoided under exclusive but not under open membership. First, additional members require that not only new members but also former members must adjust their environmental policy. The reason is that only if also former members increase their abatement efforts can it be rational for new members to join an IEA (otherwise new members have to carry additional abatement costs but receive no reward). This may cause instability and encourage former members to leave an IEA. Second, additional members may only join an IEA for reputational reasons and hence are less inclined to comply with the terms of an IEA. This may provide a bad example for other signatories. Third, additional members imply that it becomes more difficult to implement ambitious abatement targets in future amendment protocols since in most IEAs decisions can only be passed by unanimity. Consequently, comparing the theoretical results with the empirical evidence suggests that it may be worthwhile adopting exclusive membership rule that is typical for club good agreements (non-members can be excluded from the benefits of the club) also for public good agreements IEAs (nobody can be excluded from the benefits from abatement) in future environmental treaties. Though such a change of membership rule has no effect on the nature of an IEA (an IEA is and remains a public good agreement), it may nevertheless be conducive to stability of such treaties.

4.2 Number of Signatories: Grand Coalition versus Subcoalition

The empirical evidence reported in the Introduction suggests that framework conventions that only constitute declarations of intentions enjoy almost full participation but that fewer countries sign IEAs with serious and ambitious abatement obligations. The empirical evidence is much in line with the prediction of theory. The higher implemented abatement targets in an IEA are, the higher will be free-rider incentives, and the lower will be participation and compliance. Moreover, theory also provides some rationales why a *subcoalition* (an IEA comprising less than all countries) may be superior to the *grand coalition* (an IEA comprising all countries), though the grand coalition has two advantages. First, the more countries sign an IEA, the smaller is the group of outsiders, which reduces leakage effects. Second, the more countries accede to an IEA, the more countries can shoulder abatement burdens and hence the easier it is to design a cost-efficient allocation abatement scheme. In order to achieve a given global abatement target, individual countries in a subcoalition must contribute much more to cooperation compared to the grand coalition, which may drive up unit abatement costs substantially. This is particularly true if many countries with low unit costs of abatement do not accede to an IEA. However, the grand coalition has also two important disadvantages. First, the more countries sign an IEA, the more difficult it is to agree on ambitious abatement targets. Since the signature of IEAs is based on voluntary participation, agreeing on the

smallest common denominator within a large group of countries may lead to very lax environmental standards. Second, the more countries participate an IEA, the more difficult it is to enforce compliance. Overall, the net effect on the success of cooperation depends on whether the first two effects are stronger than the last two effects. From the theoretical literature it appears that *a subcoalition is superior to the grand coalition for those parameter constellations which negatively affect the success of IEAs*: a large number of countries suffering from pollution, a high benefit-cost ratio from abatement and a high degree of asymmetry between countries (see section 3).

4.3 Number of Coalitions: single versus multiple coalitions

A *single coalition structure* means that countries have only the option to accede to or to stay out of an IEA. A *multiple coalition structure* implies that countries can form regional agreements so that several IEAs may exist at the same time. Empirical evidence suggests that all IEAs regulating a particular pollutant are single agreements. In contrast, coalition models allowing for the possibility of multiple coalitions predict that several regional IEAs will form in equilibrium. The coalitions in a multiple coalition structure are not necessarily larger than the coalition in a single coalition structure because the free-rider incentive constitutes a restriction for forming larger coalitions. However, if countries can freely form coalitions, some singletons (non-signatories) in the single coalition structure will merge and form their own coalition instead of remaining non-signatories. Consequently, a *multiple coalition structure implies higher global abatement and larger global welfare than a single coalition structure*.

Comparing the empirical evidence with the theoretical findings, two controversial conjectures come to mind. First, if existing IEAs are the result of an unrestricted coalition formation process, then the predictions of the coalition models are wrong. However, it seems that this theoretical result is very robust, though, admittedly, it has been derived from stylized models. Second, if coalition formation has been restricted for institutional and/or political reasons in the past, this suggests altering the rules in the future. For instance, under the Kyoto Protocol the US insisted that they would only ratify the treaty if also developing countries would accede to this agreement. Thus, it may be the case that more could have been achieved if separate agreements were designed for industrialized countries, developing countries and countries in transition. This last remark points at the possibility to reconcile both conjectures. Taking a broader perspective, some modern IEAs, as for instance the Oslo Protocol on sulfur reductions, may be interpreted as separate agreements under the umbrella of one treaty since they impose differentiated abatement obligations on participants. In any case, the result clearly suggests that more emphasis should be placed on designing IEAs in the future, which take more care of the heterogeneous interests of countries.

4.4 Compensation Measures: monetary versus in-kind transfers

Transfers are an obvious instrument for compensating the losers from cooperation, increasing participation in an IEA and encouraging compliance. Possible compensation measures are monetary and in-kind transfers, which comprise for instance technical assistance to developing countries from industrialized countries. Whereas monetary transfers directly target at compensation, in-kind transfers do so only indirectly and hence the aim of compensation is often blurred and overlapped by other aims. Therefore, theoretically, efficiency of in-kind transfers is lower than of monetary transfers. However, the order of frequency of the application of these instruments is reversed in practice. Almost all IEAs have no provisions for monetary transfers. One prominent exception is the Montreal Protocol under which a multilateral fund has been established to which industrialized countries are supposed to contribute and where developing countries and countries in transition can

receive support. However, recipients receive only transfers for those costs (incremental costs) that occur in excess of abatement activities compared to the status quo. This implies for most developing countries that they just break even compared to the status quo. Moreover, outstanding contributions to the fund amount to roughly 12 to 16 percent per year, transfers are often delayed, some donors only issued promissory notes and some donors have fulfilled their obligations only in the form of in-kind transfers. A second prominent exception is the Convention of Biological Diversity signed in 1992 in Rio de Janeiro where developing countries can receive support from the "Global Environmental Facility". However, this fund also covers only incremental costs and the backlog of transfers is very large. A third exception, though different, is the Kyoto Protocol. Under the Clean Development Mechanism (CDM; Article 12) signatories can reduce their abatement burdens by financing "project activities resulting in certified additional emission reductions" in developing countries that are not signatories to the protocol. However, it has to be stressed that this protocol is not in force yet. In contrast to monetary transfers, the number of IEAs including provisions for technical exchange and assistance between industrialized and developing countries is larger. However, a closer reading reveals that obligations under most IEAs are very vague and promises seem often only lip service.

Hence, the empirical evidence suggests that *compensation measures are not that easily implemented in reality and that if they are implemented in-kind transfers are preferred to monetary transfers*. The theoretical literature has explained this phenomenon with *strategic behavior of governments* and with *compliance problems*. Strategic behavior applies to transfers in general and includes the following arguments. First, transfers provide an incentive for governments to strategically misrepresent their preferences. A donor has an incentive to understate its environmental preferences and overstate its abatement cost in order to convince other signatories that it should not contribute so much to an environmental fund. A recipient has an incentive to bias its stated preferences in the same direction so as to convince other countries that if it is required to contribute to a joint abatement policy at all, it should at least be generously compensated. Second, any transfer scheme must be based on some criteria that require that the welfare implications of an abatement policy are estimated and publicly disclosed. Such a transparency, however, may not be in the interest of all governments since it limits their strategic behavior in the future. Third, governments may be skeptical of paying transfers since they fear that they may be judged as weak bargaining partners which may weaken their bargaining power with respect to other issues in the future.

Compliance problems have two dimensions. First, monetary transfers create a free-rider incentive *between donor and recipient*. Either the recipient may take the transfer but does not fulfill its promised abatement obligations or the recipient fulfills its part of the deal but the donor does not pay promised transfers. In contrast, in-kind transfers, like the installation of clean technology in developing countries, suffer less from non-compliance. The reason is that it is more difficult for recipients to abuse in-kind transfers for other purposes and donors will only enjoy the benefits from transfers once they have completed the project. However, it has also been shown in the literature that the free-rider incentive of monetary transfers can substantially be reduced under the following conditions. a) If transactions happen over a longer period of time, compliance on the side of the recipient can be enforced with the threat to suspend transfer payments in the future. Thus, transfers can be used as sanctions, which will be discussed in more detail below. b) If transfers are paid in small amounts, then free-rider incentives become smaller on both sides, compliance can be checked in shorter intervals and counter measures can be faster. c) Transactions can be based on past compliance records. For this it might be helpful establishing a rating system like in financial

markets, which informs donor and recipient about the reliability of promises and behavior of payment.

Second, monetary and in-kind transfers create a free-rider incentive *within the group of donor countries*. Though the group of donors as a whole benefits from transfers through higher participation and compliance, individual donors are better off if they take a free-ride. The main problem is that it is hardly possible to control this type of free-riding behavior. Until now, no IEA has a provision that sanctions industrialized countries if they do not fulfill their transfer obligations. The only possibility is to appeal to the reputation of countries by regularly publishing the compliance record of donors. The reason that many industrialized countries prefer to fulfill their transfer obligations if at all via in-kind transfers may be that this allows for a higher participation of governmental and non-governmental organizations in donor countries. Thus, it seems that in-kind transfers are sometimes only disguised subsidies for domestic organizations.

4.5 Issue Linkage: an alternative to monetary transfers

An alternative compensation measure is issue linkage where concessions in one agreement are exchanged against concession in another agreement. Since package deals are sometimes secretly negotiated, it is not that easy to gather empirical evidence. Most reported examples include bilateral links. For instance, it has been suggested that the Columbia River Treaty of 1961 between the US and Canada, which viewed as a single issue was to the disadvantage of the US, was built on concessions by Canada involving North American defense. In the context of multilateral agreements only a wider interpretation allows to detect some form of issue linkage. One example is the Montreal Protocol where the import and export of controlled substances with non-parties is banned (Article 4). A second example is the efforts of some member states of the World Trade Organization (WTO) and non-governmental organizations not only to promote free trade within WTO but also the establishment of environmental standards in the production and consumption of traded goods and services. Both examples may be interpreted as a link between an IEA and a trade agreement. Also the provision of technical assistance and exchange under many protocols may be interpreted as a link between an IEA and an agreement to share the cost of R&D.

The empirical evidence suggests that issue linkage may be a useful instrument for cooperation. This positive conclusion is confirmed by theoretical results. On the one hand, issue linkage balances asymmetries and thus has a positive effect on profitability and compliance. However, this balancing effect can only materialize if asymmetries of issues are more or less mirror images. Moreover, in contrast to monetary and in-kind transfers, which balance asymmetries between countries, issue linkage balances asymmetries between issues. Therefore, compliance problems between donor and recipient are less important than in the case of monetary transfers since each country is not only a donor but also a recipient. However, the compliance problem within the group of donor countries, as observed for monetary and in-kind transfers, is also a problem. In the case of more than two countries each country has an incentive not to offer its preferred issue for compensation. This point may explain why issue linkage has been observed mainly in the context of bilateral agreements.

On the other hand, issue linkage can have a positive effect on participation if an IEA is linked to another agreement that enjoys a higher participation. Agreements with potentially higher participation are in particular club good agreements in which the gains from cooperation are exclusive to signatories and therefore free-riding is of minor importance. Typical club good agreements include agreements on R&D and trade agreements. Under an R&D agreement firms in

signatory countries share the costs of R&D, implying that those firms reduce their marginal and average production costs compared to firms in non-signatory countries. The lower spillovers of R&D to outsiders are, the higher is the degree of excludability and the larger is the competitive advantage of firms in signatory over firms in non-signatory countries. Also in a trade agreement firms in signatory countries have a competitive advantage over outsiders through external trade barriers (e.g., tariffs or trade bans). Thus, the strategy of this type of issue linkage is to raise the incentive for countries to contribute to pollution abatement via the threat that if they do not join the linked agreement they will also not enjoy the benefits from the club good agreement. Though this strategy is generally successful, it may not work if there are strong incentives in the club good agreement to limit the number of participants for strategic reasons.

Thus, theory generally draws a positive picture of issue linkage, though at least two problems will limit the application of this instrument in practice. First, negotiating several issues will be a time consuming business in the context of multilateral agreements comprising many countries. Therefore, it is not surprising that issue linkage has been mainly used in the bilateral context. Second, in reality, membership will be mixed. It is hard to imagine that countries are excluded from a trade agreement or defense pact if they do not sign an IEA. In the context of the Montreal Protocol this was no problem since the trade agreement part was simultaneously created with the environmental agreement part of this protocol and trade sanctions apply only to those products regulated under this protocol.

4.6 Global Abatement Levels: less is more

As mentioned in the Introduction, global abatement levels usually fall short of what would be required from the globally optimal solution, questioning the effectiveness of past IEAs. From a theoretical point of view, this is not surprising. First, as has been pointed out and explained previously, the higher the global abatement level, the higher are free-rider incentives. Thus, it suffices to stress here that this result is very general and holds irrespective of the allocation of abatement burdens. Second, most IEAs require agreement by consensus. Thus, signatories will usually only agree on the *smallest common denominator*, implying that only moderate global abatement levels can be implemented. However, what is more surprising is that in the presence of free-rider incentives the apparent disadvantage of low abatement levels may turn out to be an advantage. On the one hand, moderate abatement levels imply a higher rate of compliance, which may compensate higher abatement levels but a lower rate of compliance. On the other hand, moderate abatement levels lead to a higher participation, which may compensate higher abatement levels but a low participation. In other words, sometimes, less is more! Though what "sometimes" means has not exactly been established in the literature, it appears that less is more for those parameter constellations (large asymmetries, large number of affected countries and high benefit-cost ratio), which imply high free-rider incentives (see section 3).

4.7 Allocation of Abatement Levels: command and control versus market-based instruments

As mentioned in the Introduction, individual abatement levels are usually not allocated cost-efficiently. Many IEAs apply the *command and control instrument uniform emission reduction quotas*. In contrast, cost-efficient *market-based instruments*, like *emission taxes* and *emission permits*, have not been applied in past IEAs. The only exception is the Kyoto Protocol that allows for permit trading under Article 17. However, despite very long negotiations until now, no final agreement could be reached on the design of the permit system and currently it is not evident

whether it will eventually be implemented. In the literature the following points have been made to explain this phenomenon.

First, uniform emission reduction quotas are inefficient as long as countries are heterogeneous since they do not consider that unit abatement costs differ across countries. However, they possess three important advantages that may explain their frequent appearance. a) Uniform abatement obligations constitute some kind of a focal point on which countries can agree easily. This saves negotiation time and therefore transaction costs. b) Countries negotiating about uniform emissions reduction quotas require only information about present emissions in order to put forward a proposal. Given that information about abatement costs and benefits from abatement are uncertain for most pollutants, this limits the possibility of strategic offers. c) Uniform emission reduction quotas imply that all countries contribute the same amount in relative terms compared to the status quo. Therefore, they lead to a relatively symmetric distribution of the gains from cooperation. This has the advantage that for not too high abatement levels profitability will not be violated and compliance and participation will be relatively high. Moreover, given the need for consensus, it can be shown that critical countries agree on relatively high abatement levels compared to other policy instruments.

Second, emission taxes and emission permits imply an efficient allocation of abatement burdens. However, in the presence of free-rider incentives, they possess some disadvantages, which may explain that they have not been applied in the past. The disadvantages include the following items. a) Taxes lead to an asymmetric distribution of the gains from cooperation in the case of asymmetric countries, which may violate profitability and which implies high free-rider incentives. Hence, critical countries agree if at all only on moderate abatement levels. b) One possibility to avoid asymmetries could be the implementation of an *international tax* by an international environmental agency that balances asymmetries via the reallocating of tax revenues. However, since it can be expected that governments show a great reluctance to hand over their tax sovereignty to an international body, this option seems not feasible. c) Another possibility could be the implementation of a *national tax* where those governments, which benefit more than proportionally from cooperation, transfer some of their tax revenues to other countries. However, this option faces the same free-rider problems as mentioned under monetary transfer. d) Negotiations on national and international taxes require information on abatement costs in order to estimate the economic reactions of industry. This gives much leeway to governments to make strategic proposal during negotiations since this information is uncertain by its nature. e) Tradable emission permits imply monetary transfers between those countries buying and those selling permits. Hence, these transactions are also subject to free-riding. This may explain why under the Kyoto Protocol a second trading system without monetary transactions has been established. Under Joint Implementation (Article 3 and 4) signatories can jointly meet their targets in the form of a bubble. f) Though the mode of allocating emission permits has no effect on efficiency, it affects distribution. Therefore, tough bargaining among negotiators about the initial permit allocation can be expected. g) Also negotiations about the allocation of permits require information on abatement costs and hence strategic bargaining will hamper quick agreement.

However, despite the disadvantages of market-based instruments, they may play some role in future IEAs. Based on the discussion above, a blue print of implementation could look as follows. In a first step uniform emission reduction quotas are allocated and trading is only allowed among those countries that can credibly promise to monitor and enforce transactions. Permit trading should only be allowed between countries and not between industries across borders since this eases the control

of transactions. In a second step, after some experience has been gained from permit trading, the permit system may be expanded to allow for trade among private entities across borders and to include more countries in order to raise efficiency of a permit system.

4.8 Sanctions

Obvious measures to control free-riding are sanctions. However, empirical evidence tells us that most IEAs have no provision for sanctions. Probably, the only exception of *sanctioning non-participation* is the above-mentioned Article 4 under the Montreal Protocol, which imposes trade sanctions on non-signatories. For *sanctioning non-compliance* most IEAs have only a provision for the establishment of an arbitration and dispute settlement committee if a party accuses another of violating the spirit of an agreement. Due to the voluntary character of these arbitration schemes and since provisions contain no threats of punishment, it is not surprising that there are no reported instances of application. Again, the Montreal Protocol is an exception where the parties first agreed on an indicative list of measures (Annex V) at their 4th meeting in Copenhagen in 1992 and then defined non-compliance at their 6th meeting in Nairobi in 1994. The measures include a) assistance for the collection and the reporting of data, technical assistance, technology transfers and financial assistance, b) issuing cautions and c) suspension of specific rights and privileges including transfers of technology, financial mechanism and institutional arrangements. It is evident that only the last item can be regarded as sanctions and obviously can only be used against developing countries. For instance, if a developing country does not report baseline data within one year, they are no longer given Article 5 status. This status exempts these countries from certain regulations and allows them drawing on financial assistance. However, any formal statement of non-compliance by the Implementation Committee has to be passed by unanimity, which hampers quick implementation of sanctions. Another exemption is the Kyoto Protocol where the parties agreed at the meeting in Marrakech in 2001 on "Consequences Applied by the Enforcement Branch" (Annex XV). Similar to the Montreal Protocol, most measures include assistance to meet the targets rather than tough sanctions and complicated voting procedures precede any formal statement of non-compliance. However, two tough punishment options have been decided: A party a) may be excluded from the emission trading system and b) must reduce 30 percent more of its assigned emissions in the second commitment period (2013-2017). It remains to be observed whether these sanctions will be used in the future.

The empirical evidence on sanctions suggests that the design of effective sanctions faces various problems. From a theoretical point of view, this not surprising because of the following reasons.

1) Sanctioning countries for not acceding to an IEA is at odds with the notion of voluntary participation. That the Montreal Protocol is the only exception may be due to strong lobbying of the US industry for trade sanctions against outsiders. Since US-industry had developed substances that could replace CFCs, involving a high level of technical know-how, they had a strong interest to secure their competitive advantage over developing countries, which could only compete with cheap CFCs.

2) Sanctions often have also a negative effect on those countries carrying out the punishment. Thus, harsh sanctions are not always credible and constitute themselves a public good that is subject to free-riding. This explains not only in the environmental context why governments are often reluctant to impose sanctions against other countries and why for instance trade embargoes frequently failed in the past.

3) Sanctioning non-compliance is flawed by the fact that under most treaties signatories can withdraw from the agreement after giving notice 3 (Kyoto Protocol, Article 27) or 4 years (Montreal Protocol, Article 19) in advance. Thus, sanctions can only last for a few months and must be moderate since otherwise a country leaves an IEA to avoid punishment.

4) Coordination of sanctions among signatories is time consuming and costly and therefore will often be delayed. A solution to this problem could be the establishment of simple and transparent punishment procedures. However, simple means also suboptimal punishment and hence a lower threat to free-riding.

5) Trade sanctions may be in conflict with the regulations of WTO and may jeopardize stability of other agreements.

In the light of these problems, the enforcement measures under the Montreal and Kyoto Protocol can be evaluted as follows.

1) The suspension of transfers as suggested under the Montreal Protocol in the case of treaty violations perfectly satisfies the conditions of renegotiation-proof punishment, though this type of sanctions can only be used against developing countries. First, punishers (industrialized countries) do not suffer a disadvantage from this punishment since donors are better off if they do not pay transfers. Second, the punished countries (developing countries) can be provided with an incentive to accept this punishment. For this it is important the punishment lasts not too long and that the punishers clearly indicate under which conditions they will resume payments so that treaty violators have an incentive to remain in an IEA.

2) The exclusion from the emission trading system, as suggested under the Kyoto Protocol, seems a less clever strategy. The reason is that permit trading takes place voluntarily and hence trading implies a win-win situation. Consequently, excluding a country from trading will also harm punishers. A solution to this problem could be the following modification. Instead of excluding a seller of permits from trading, its revenues are transferred to an environmental fund for some time. Instead of excluding a buyer of permits from trading, this country should pay a mark-up on the ordinary permit prices. In both cases, the surplus can be used for compensation of other signatories. These measures also point to another role of transfers for sanctioning treaty violators in a renegotiation-proof way. If each country were to pay transfers into an environmental fund, then similarly to union funds, which are used to back up strikes by reducing the negative effect of strikes on their members (suspension of payment, lay-off of workers and so forth), this money could be used to mitigate the negative effects of sanctions for punishers. This would improve upon the credibility of sanctions.

3) A change of abatement levels is another alternative instrument for sanctioning violation of treaty obligations. On the one hand, each government will recognize that if it does not meet its reduction duties, other governments have the right to follow suit according to the principle of reciprocity and reduce their abatement efforts too. On the other hand, once abatement measures have been taken, it is not that easy for punishers to reduce their abatement efforts. In particular, most abatement measures involve high set-up costs that would be "sunk" if punishers changed their environmental policy. But also treaty violators are also not very flexible in increasing their abatement efforts in the short-run as a sign of repentance in order to return to normal terms as quickly as possible. Moreover, generally, a reduction of abatement efforts can only harm countries that evaluate

environmental damages sufficiently high. Consequently, this type of sanction cannot be used against developing countries but only against industrialized countries.

In the light of these preliminary remarks, the 30 percent additional emission reduction of treaty violators as suggested under the Kyoto Protocol seems to be a punishment strategy in the right direction. a) All important signatories are industrialized countries or countries in transition and hence the suspension of transfers as suggested by the Montreal Protocol would be no feasible option. b) Additional abatement efforts by treaty violators compensate countries that comply with their treaty obligations. Thus, punishers suffer no disadvantage from sanctions. c) Punishment in the second and not in the first commitment period allows the treaty violator more flexibility to meet its obligations. d) However, the time gap between treaty violation and sanctions reduces the threat potential of sanctions if governments discount time. In particular, the government responsible for treaty violation and the government, which has to conduct additional abatement efforts, may not be the same. Hence, it is easy for the successor government to claim that it is not responsible for the misconduct of previous governments. However, this problem could easily be solved with the following modification. Punishment starts immediately but at low levels and punishment duties are allocated over a longer period of time in order to ensure flexibility. In order to provide governments with an incentive to implement additional abatement measure fast, immediate action should be rewarded with generous reductions of future abatement obligations. e) Sanctions are to weak in case a country continuously violates a treaty and shows no reprentance. Therefore, the Kyoto Protocol should include a threat that signatories will reduce their abatement efforts if the treaty violator continues with ignoring the rules of the protocol.

5. Summary and Conclusions

The lack of a supranational enforcement authority makes it difficult in reality to implement first or second best solutions for international pollution problems. Three main obstacles have been identified. First, cooperation may not be profitable for all countries if participants to an IEA face different abatement costs and benefits from abatement. Second, even if an IEA would be profitable to all participants, individual countries face two types of free-rider incentives. The first type is to remain a non-signatory (non-participation) and the second type of is to violate the spirit of an IEA (non-compliance). The reason is that nobody can be excluded from the public good clean environment provided by those countries that participate in IEA and comply with its terms. Paradoxically, under those conditions where cooperation would generate large global welfare gains, free-riding is particularly pronounced. Unfortunately, there are no straightforward counter measures to neutralize free-rider incentives. Since accession to an IEA is voluntarily only carrots can be used to increase participations, which, however, may be subject to free-riding itself. Also the stick cannot always be used to punish non-compliance since sanctions have to be credible. Thus, there is no universal instrument that can solve all problems. Therefore, a mix of instruments has to be used in order to narrow the gap between actual IEAs and first and second best solutions. Some of the most promising steps in this direction that have been mentioned in the text are the following.

1) Transfers may be used to provide developing countries and countries in transition with an incentive to join an IEA. If those countries do not fulfill their treaty obligations, a credible punishment is to suspend transfer payments for some time. 2) Non-compliance of industrialized countries can be punished by other participants through a reduction of abatement efforts and the enforcement of obligations that the violator has to increase its abatement efforts for some time. However, this punishment will only work if the violator accepts his additional duties. Therefore,

punishment obligations must be flexible and the punished country must be rewarded with the prospect that cooperation is resumed soon. 3) Governmental and non-governmental organizations should regularly publish the status of ratification, the overall success of a treaty as well as the compliance records and abatement obligations of individual countries. This puts environmental conscious voters in the position to put pressure on their governments and encourages reputation effects. 4) Cooperation on research and development may create economies of scale effects. This can reduce abatement costs and may thus encourage participation in IEAs. 5) Abatement obligations may be implemented into national law that makes it more difficult for governments to violate the terms of IEAs. 6) For regional environmental problems issue linkage may be a successful strategy to balance asymmetries between countries in order to raise participation and compliance. 7) For global environmental problems several regional agreements among relatively homogenous countries may be superior to a global agreement since the individual interests of participants can be better accounted for. 8) Small IEAs may be superior to large IEAs since more ambitious abatement targets can be implemented and compliance can be better enforced. However, if leakage effects are strong, this relation may be reversed and initiators should strive for large participation.

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Overview Articles and Books on the Game Theoretical Analysis of IEAs

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Protocol	Objectives	Status of Membership
Framework Convention on Climate Change (FCCC)	framework convention preceeding the Kyoto Protocol; expresses concern about climate change due to greenhouse gases; no binding emission ceilings were set	signed in Rio de Janeiro in 1992 by 166 countries; entered into force in 1994; presently counts 186 parties
Kyoto Protocol	targets at a reduction of greenhouse gas emissions of 5.2 percent based on 1990 emission levels to be achieved in the period 2008-2012; emission reduction of major emitters between 6 and 8 percent	signed in Kyoto in 1997 by 38 countries; has not yet entered into force
Vienna Convention	framework convention precceeding the 5 subsequent protocols; expresses concern about the depletion of the ozone layer through CFCs and halons, no binding emission ceilings were set	signed in Vienna in 1985 by 28 countries, entered into force in 1988, currently counts 182 parties
Montreal Protocol	CFCs have to be cut to half of 1986 levels by 1999; starting with a freeze of production and consumption within one year after the protocol will be in force; freeze of halons at 1986-levels	signed in Montreal in 1987 by 46 countries; entered into force in 1989, currently counts 181 parties
London amendment to the Montreal Protocol	further reduction of CFCs; complete phase-out by 2000; new substances were included in the list of harmful substances	signed in London in 1990; entered into force in 1992; currently counts 153 parties
Copenhagen amendment to the Montreal Protocol	tightening of the timetable for the reduction of ozone depleting substances; most substances have to be eliminated by 1996	signed in Copenhagen in 1992; entered into force in 1994; presently counts 128 parties
Montreal amendment to the Montreal Protocol	tightening of the timetable for the phaseout of methyl bromide; establishment of a new licensing system for controlling trade ozone depleting substances	signed in Montreal in 1997; entered into force in 1999; currently counts 63 parties
Beijing amendment to the Montreal Protocol	establishment of monitoring system to control bromochloromethane and new trade rules for hydrochloroflurocarbons (HCFCs) that were developed as replacements for CFCs	signed in Beijing in 1999; entered not into force yet, presently 11 signatories
Convention on Long-Range Transboundary Pollution (LRTAP)	framework convention preceeding the subsequent 4 protocols (and other protocols); expresses concern about transboundary pollution problems (e.g., acidification of lakes and soils)	signed in Geneva in 1979 by 33 countries; entered into force in 1983; currently counts 48 parties
Helsinki Protocol	targets at 30 percent reduction of sulfur emissions based on 1980 levels by 1993	signed in Helsinki in 1985 by 19 countries; entered into force in 1987; currently counts 22 parties
Sofia Protocol	targets at uniform freeze of nitrogen oxides at 1987 levels by 1995	signed in Sofia in 1988 by 25 countries; entered into force in 1991; currently counts 28 parties
Geneva Protocol	targets at 30 percent reduction of volatile organic compounds based on 1998 levels by 1999	signed in Geneva in 1991 by 23 countries; entered into force in 1997; currently counts 21 parties; 5 signatories have not yet ratified the treaty; 3 countries acceeded later
Oslo Protocol	follow-up protocol of the Helsinki Protocol; sets tighter non-uniform emission ceilings to be achieved by 2000 so that critical loads are not exceeded	signed in Oslo 1994 by 28 countries; entered into force in 1998; currently counts 24 parties; 4 signatories have not yet ratified the treaty
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	banning of commercial international trade with endangered species	signed in Washington D.C. in 1973 by 47 countries; entered into force in 1975; currently counts 152 parties

The International Convention for the Regulation of Whaling (ICRW)	establishment of a system of international regulations to ensure the conservation and development of whale stocks	signed in Washington D.C. in 1946 by 15 countries; entered into force in 1948; currently counts 48 parties
The Waigani Convention	regional convention in the South Pacific region to ban the importation of hazardous and radioactive wastes and to control the movement of these substances	signed in Waigani, Papua New Guinea, in 1995 by 14 countries; entered into force in 2001; currently counts 8 parties; 7 signatories have not yet ratified the treaty
The Columbia River Treaty	coordination of flood control and electrical energy production in the Columbia River Basin between the United States and Canada	signed in 1961 by the USA and Canada; further negotiations resulted in a protocol signed and ratified in 1964.

Legend: Signature means the formal acceptance of treaty targets by the negotiators of a treaty. Ratification is the formal confirmation and approval of a treaty that is necessary for a treaty to become binding. Accession means that a state is not among the original negotiators (signatories) and enters a treaty at a later stage. Accession implies de facto signature and ratification at the same time. Entry into force means that treaty provisions become binding, which requires usually a certain number of ratifications and/or accessions. Signatories comprise countries that signed a treaty and parties comprise countries which deposited their formal confirmation and approval of a treaty through ratification or accession.

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(lix) This paper was presented at the ENGIME Workshop on "Mapping Diversity", Leuven, May 16-17, 2002
(lx) This paper was presented at the EuroConference on "Auctions and Market Design: Theory, Evidence and Applications", organised by the Fondazione Eni Enrico Mattei, Milan, September 26-28, 2002
(lxi) This paper was presented at the Eighth Meeting of the Coalition Theory Network organised by the GREQAM, Aix-en-Provence, France, January 24-25, 2003
(lxii) This paper was presented at the ENGIME Workshop on "Communication across Cultures in Multicultural Cities", The Hague, November 7-8, 2002
(lxiii) This paper was presented at the ENGIME Workshop on "Social dynamics and conflicts in multicultural cities", Milan, March 20-21, 2003
(lxiv) This paper was presented at the International Conference on "Theoretical Topics in Ecological Economics", organised by the Abdus Salam International Centre for Theoretical Physics - ICTP, the Beijer International Institute of Ecological Economics, and Fondazione Eni Enrico Mattei – FEEM Trieste, February 10-21, 2003
(lxv) This paper was presented at the EuroConference on "Auctions and Market Design: Theory, Evidence and Applications" organised by Fondazione Eni Enrico Mattei and sponsored by the EU, Milan, September 25-27, 2003
(lxvi) This paper has been presented at the 4th BioEcon Workshop on "Economic Analysis of Policies for Biodiversity Conservation" organised on behalf of the BIOECON Network by Fondazione Eni Enrico Mattei, Venice International University (VIU) and University College London (UCL) , Venice, August 28-29, 2003
(lxvii) This paper has been presented at the international conference on "Tourism and Sustainable Economic Development – Macro and Micro Economic Issues" jointly organised by CRENoS (Università di Cagliari e Sassari, Italy) and Fondazione Eni Enrico Mattei, and supported by the World Bank, Sardinia, September 19-20, 2003
(lxviii) This paper was presented at the ENGIME Workshop on "Governance and Policies in Multicultural Cities", Rome, June 5-6, 2003
(lxix) This paper was presented at the Fourth EEP Plenary Workshop and EEP Conference "The Future of Climate Policy" , Cagliari, Italy, 27-28 March 2003

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