INTERNATIONAL COOPERATION TO RESOLVE INTERNATIONAL POLLUTION PROBLEMS

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Keywords: international pollution, international environmental agreements, treaty design, coalition theory

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Summary

This chapter provides an 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 chapter attempts to answer these questions after giving an informal introduction to coalition models.

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.

Protocol	Objectives	Status of Membership
Framework Convention on Climate Change (FCCC)	framework convention preceding 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 preceding 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	further reduction of CFCs; complete	signed in London in 1990;

the Montreal Protocol	phase-out by 2000; new substances were included in the list of harmful substances	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 phase out 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 preceding 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 acceded 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	coordination of flood control and	signed in 1961 by the USA and

Treaty	electrical energy production in the Columbia River Basin between the United States and Canada	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.

Table 1. International Environmental Agreements: Selected Overview

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 the regional implications see also *Environmental conflicts and regional conflict management*). 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 into 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 (see *International environmental agreements and the case of global warming*). 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 most as third best solutions. This will be illustrated with some empirical evidence that the author structures according to the following four features.

1.1. 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, 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 abovementioned 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.

1.2. 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 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.

1.3. Effectiveness

The few empirical studies measuring the effectiveness of IEAs suggest that implemented abatement levels are close to those which countries would have implemented anyway if they had pursued their self-interest noncooperatively (national environmental policy). This has been confirmed for instance for the abovementioned 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.

1.4. 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:

- Why is there a difference between actual IEAs and first and second best solutions?
- Which factors determine this difference?
- Which measures can help to narrow this difference?

The answer depends by and large on the field and method of the analysis. In this chapter the author surveys 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 noncooperative 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 the author provides in Section 2 an informal sketch of the structure of coalition models and a preliminary answer to the first question raised above. Subsequently, the author discusses 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.

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Bibliography

Overview Articles and Books on the Game Theoretical Analysis of IEAs

Barrett S. (1997). Toward a Theory of International Environmental Cooperation. *New Directions in the Economic Theory of the Environment* (ed. C. Carraro and D. Siniscalco), pp. 239-280. Cambridge: Cambridge University Press. [Extensive technical overview article on coalition models that analyze the formation of IEAs.]

Barrett S. (1998). On the Theory and Diplomacy of Environmental Treaty-Making. *Environmental and Resource Economics*, Vol. 11, pp. 317-333. [Non-technical paper using results of game theoretical analyses of IEAs to discuss the effects of treaty design for the success of cooperation.]

Barrett S. (1999). Montreal versus Kyoto, International Cooperation and the Global Environment. *Global Public Goods: International Cooperation in the 21st Century* (ed. I. Kaul, I. Grunberg and M. Stern), pp. 192-219. Oxford: Oxford University Press. [Non-technical paper using results of game theoretical analyses of IEAs to analyze important institutional features of the Kyoto and Montreal Protocol.]

Carraro C. (2000). Roads towards International Environmental Agreements. *The Economics of International Environmental Problems* (ed. H. Siebert), pp. 169-202. Tübingen: Mohr Siebeck. [Paper discussing new developments of coalition theory for the analysis of IEAs.]

Carraro C. and Siniscalco D. (1992). The International Dimension of Environmental Policy. *European Economic Review*, Vol. 36, pp. 379-387. [Non-technical overview paper on P-models analyzing IEAs.]

Carraro C. and Siniscalco D. (1998). International Environmental Agreements: Incentives and Political Economy. *European Economic Review*, Vol. 42, pp. 561-572. [Short non-technical overview article using game theory to analyze IEAs.]

Finus M. (2001) Game Theory and International Environmental Cooperation. Cheltenham: Edward Elgar. [Book on the game theoretical analysis of IEAs. Covers all basic but also sophisticated issues discussed in this article at a technical advanced level. Provides many references on background papers.]

Finus M. (2002). Game Theory and International Environmental Cooperation: Any Practical Application? *Controlling Global Warming: Perspectives from Economics, Game Theory and Public Choice* (ed. C. Böhringer, M. Finus and C. Vogt), ch. 2. Cheltenham: Edward Elgar. [Critical overview paper on the game theoretical analysis of IEAs. Discusses the applicability of theory for policy conclusions. Covers many aspects discussed in this article, using some mathematics. Provides many references on background papers.]

Finus M. (2003a). Stability and Design of International Environmental Agreements: The Case of Transboundary Pollution. In: Folmer, H. and T. Tietenberg (eds.), *International Yearbook of Environmental and Resource Economics*, 2003/4, Edward Elgar, Cheltenham, UK, 2003, ch. 3, pp. 82-158. [Extensive and non-technical overview article on the analysis of IEAs with coalition models. Covers almost all aspects discussed in this article. Provides many references on background papers.]

Finus M. (2003b). New Developments in Coalition Theory: An Application to the Case of Global Pollution. In: Marsiliani, L., M. Rauscher and C. Withagen (eds.), *Environmental Policy in an International Perspective*, Kluwer, Dordrecht, Holland, 2003, pp. 19-49. [Paper discussing new developments of coalition theory for the analysis of IEAs.]

Folmer H., and van Mouche P. (2000). Transboundary Pollution and International Cooperation. *The International Yearbook of Environmental and Resource Economics* (ed. T. Tietenberg and H. Folmer). Cheltenham and Brookfield: Edward Elgar. [Technical overview paper on the game theoretical analysis of IEAs.]

Mäler K.-G. (1990). International Environmental Problems. *Oxford Review of Economic Policy*, Vol. 6, pp. 80-108. [Overview article on the game theoretical analysis of international environmental problems.]

Papers on the Effectiveness of IEAs

Böhringer, C. and C. Vogt (2004), The Dismantling of a Breakthrough: The Kyoto Protocol as Symbolic Policy. "*European Journal of Political Economy*", vol. 20(3), pp. 597-618. [Paper questioning the effectiveness of the Kyoto Protocol using basic statistical data.]

Finus M. and Tjøtta S. (2003). The Oslo Protocol on Sulfur Reduction: The Great Leap Forward? *Journal of Public Economics*, vol. 87, 2003, pp. 2031-2048. [C-model that analyzes stability of the Oslo Protocol based on empirical data. Shows that the Oslo Protocol is an ineffective IEA but also stresses that the implementation of ambitious abatement targets is difficult due to large asymmetries between countries.]

Murdoch J.C. and Sandler T. (1997a). Voluntary Cutbacks and Pretreaty Behavior: The Helsinki Protocol and Sulfur Emissions. *Public Finance Review*, Vol. 25, pp. 139-162. [Paper using regression analysis to demonstrate that the Helsinki Protocol has not been an effective treaty.]

Murdoch J.C. and Sandler T. (1997b). The Voluntary Provision of a Pure Public Good: the Case of Reduced CFC Emissions and the Montreal Protocol. *Journal of Public Economics*, Vol. 63, pp. 331-349. [Paper using regression analysis to demonstrate that the Montreal Protocol has not been an effective treaty.]

Werksman J. (1997). Five MEAs, Five Years since Rio: Recent Lessons on the Effectiveness of Multi-lateral Agreements. Foundation for International Environmental Law and Development, Special Focus Report. London: FIELD. [Report on a study on the effectiveness of IEAs.]

Studies on Compliance and Sanctions

Brown Weiss E. and Jacobson H. K. (1997). Compliance with International Environmental Accords. *International Governance on Environmental Issues* (ed. M. Role, H. Sjöberg and U. Svedin), pp. 78-110. Dordrecht, The Netherlands: Kluwer. [Non-technical paper analyzing compliance with IEAs.]

Jordan A. and Werksman J. (1996). Financing Global Environmental Protection. *Improving Compliance with International Environmental Law* (ed. J. Cameron, J. Werksman and P. Roderick), pp. 247-255. London: Earthscan. [Non-technical paper on compliance of IEAs.]

Keohane R.O. (1995). Compliance with International Standards: Environmental Case Studies. *Proceedings of the Eighty-Ninth Annual Meeting of the American Society of International Law* (ed. J.L. Hargrove), pp. 206-224. Buffalo, NY: Hein&co. [Non-technical paper on compliance of IEAs.]

Victor G. (1998). The Operation and Effectiveness of the Montreal Protocol´s Non-Compliance Procedure. *The Implementation and Effectiveness of International Environmental Commitments: Theory and Practice* (ed. D.G. Victor, K. Raustiala and E.B. Skolnikoff), pp. 137-176. Laxenburg: MIT Press. [Non-technical paper on sanctions under the Montreal Protocol.]

Biographical Sketch

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