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Incentives for International Environmental Cooperation:

Theoretic Models and Economic Instruments

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Abstract:

This paper surveys the rapidly growing theoretical literature on international environmental agreements. The surveyed contributions are classified according to the conceivable strategies to create incentives for the participation in and compliance with environmental conventions. The proposed taxonomy of instruments consists of (i) the choice and particular form of the internalization instrument; (ii) carrot-stick strategies that make cooperative pollution reductions dependent on the past behavior of other countries (internal stabilization); (iii) transfers and sanctions of various forms (external stabilization); (iv) unilateral and accompanying measures by single countries or subcoalitions; and (v) long-term provisions to increase the flexibility of agreements and to improve the framework conditions for international negotiations.

JEL-classification: D62, D7, F02, H21, Q28

Keywords: international environmental agreements, cooperation, transboundary environmental externalities, incentive compatibility, enforcement

Non technical summary:

Which strategies can be pursued to create incentives for international environmental cooperation? This paper addresses the above question by surveying the rapidly growing theoretical literature on international environmental agreements and by categorizing the conceivable instruments to stimulate and sustain international cooperation on transboundary pollution control. Many environmental problems share the features that a great number of countries is involved and that a substantial heterogeneity of these countries can be observed.

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These features make it difficult to coordinate environmental policies effectively. Firstly, when countries are very asymmetric with respect to the benefits and costs of emission abatements some of them may not profit from environmental cooperation although they contribute to pollution and therefore should be part of a cooperative solution. This holds obviously for unidirectional externalities. In such cases compensation payments to upstream countries are required which may be difficult to implement on the international level. It holds also for the case of reciprocal externalities where the additional problem arises how to allocate the measures in a way that minimizes overall abatement costs. Secondly, even in the extreme case of identical countries each government has an incentive to abstain from an agreement and to take a free ride on the efforts of cooperating countries as long as its own abstention does not lead to a total breakdown of environmental cooperation. Especially when a great number of countries is involved it is difficult to create the necessary *participation incentives* so that all relevant countries become party of an environmental treaty.

A second core problem of cooperative approaches in international environmental policy is the lack of a supranational authority that could enforce formal agreements between sovereign states. It implies that national governments cannot credibly commit themselves to the obligations stipulated in an environmental convention. The same free-rider incentives that make countries not participate in a coordination of environmental policies thus lead to an intrinsic instability of agreements. The stability problem is especially severe when many countries are involved, but it is not trivial even for only a few countries. Therefore, international environmental agreements must be designed to provide as well appropriate *compliance incentives*. In general, strategies to promote international environmental cooperation influence both the incentives for participation and compliance.

The paper offers a systematic categorization of the various conceivable instruments to create cooperation incentives. The surveyed contributions are grouped according to how closely the analyzed instruments are related to the environmental policies of the governments. Starting with the choice and design of the internalization instrument itself (i.e. emission taxes, tradable permits, quotas etc.) we gradually enlarge the strategy space of the players (the national governments) and increase the complexity of the underlying decision problem to discuss the additional instruments that are possible in those contexts, respectively. The strategy space is expanded by adding the time dimension to the decision problem – i.e. by assuming repeated decisions on pollution abatement – and by allowing for compensations in various forms as an additional instrument variable. The underlying decision problem is extended to take into account utility interdependencies (i.e. additional arguments in utility/welfare functions) and interdependencies with other markets (i.e. general equilibrium effects). Accordingly, the proposed taxonomy of instruments consists of (i) the choice and particular form of the internalization instrument; (ii) carrot-stick strategies that make cooperative pollution reductions dependent on the past behavior of other countries (internal stabilization); (iii) transfers and sanctions of various forms (external stabilization); (iv) unilateral and accompanying measures by single countries or subcoalitions; and (v) long-term provisions to increase the flexibility of agreements and to improve the framework conditions for international negotiations. The survey devotes a section to each of the above types of instruments. It closes with an assessment of the central merits and shortcomings of the surveyed literature and a brief outlook for future research.

1 Introduction

The 1990s have been imbued by a growing concern for international and especially global environmental problems. This is reflected by political debates and activities on the international level as for example the United Nations Conference on Environment and Development (UNCED) 1992 in Rio de Janeiro. At the same time it has been an intensively discussed issue in the academic sphere. The economic analysis of environmental problems was subject of intensive research already in the 1960s and 1970s. Nevertheless, the increasing preoccupation with transboundary externalities led to a renaissance of research in environmental economics and to a new body of literature. The basic reason for a re-formulation of the research program has been concisely summarized by Carraro and Siniscalco (1992): *Standard solutions for [transboundary, C.S.] environmental externalities are therefore not available, and the protection of the international commons is left to voluntary agreements among sovereign countries. It is precisely this fact which requires a shift in our analyses, from a literature on government intervention to a literature on negotiation between nations and international policy coordination.*

Transboundary environmental externalities do not represent an exceptional class of environmental problems but can be seen as the standard form of detrimental externalities between individuals sharing common natural resources. The environmental impact of economic activity does not stop at politically determined national borders, but depends on complex biological and physical regularities. Consequently, the spatial dimension of an environmental problem is often not congruent to the areas of political jurisdiction and national governments are not competent to pursue a centralized regulation. These problems must be addressed on the international or even global level in a decentral manner by voluntary agreements among the countries concerned.

Many environmental problems share the features that a great number of countries is involved and that a substantial heterogeneity of these countries can be observed with respect to economic, environmental and other characteristics. These features make it difficult to coordinate environmental policies effectively. Although cooperating on the use of international environmental resources is improving global welfare by definition and not a zero-sum-game, single countries may nevertheless lose from participating in an international environmental

agreement. Firstly, when countries are very asymmetric with respect to the benefits and costs of emission abatements some of them may not profit from environmental cooperation at all although they contribute to pollution and therefore should be part of a cooperative solution. This holds obviously for unidirectional externalities. In such cases compensation payments to upstream countries are required to reach some kind of Coasian bargaining solution. In case of more than one polluting country the additional problem arises how to allocate the measures in a way that minimizes overall abatement costs. Again the allocation of abatement efforts that is internationally cost-effective may not be profitable for some countries without any compensation. Secondly, even in the extreme case of identical countries each single government has an incentive to abstain from an agreement as long as its own abstention does not lead to a total breakdown of environmental cooperation. The public-good character of environmental policy implies that outsider countries benefit from the efforts of cooperating countries without incurring any own costs. This incentive to free ride on the efforts of other countries is the stronger the more countries are involved because the behavior of a single country then is only of minor importance for the cooperative outcome. Taken together, in many situations it is difficult to create the necessary *participation incentives* so that all relevant countries become party of an environmental treaty.

An additional problem of cooperative approaches in international environmental policy is the lack of a supranational authority that could enforce formal agreements between sovereign states. It implies that national governments cannot credibly commit themselves to the obligations and actions stipulated in an environmental convention. Thus, the same free-rider incentives that make countries not participate in a coordination of environmental policies also lead to an intrinsic instability of agreements. The stability problem is especially severe when many countries are involved, but it is not trivial even for only a few countries. Therefore one has to provide as well appropriate *compliance incentives* that render cooperation incentive compatible once an environmental convention has come into force. From a global perspective the basic economic problem thus is to maximize aggregate welfare gains from international environmental cooperation subject to the above two types of incentive constraints. This translates into the question how an agreement should be designed with respect to the international environmental standard, the way the required policy measures are assigned to the different contracting parties, and with respect to additional treaty provisions and measures to increase its effectiveness and stability.

The purpose of this paper is to address the above question by giving an up-to-date survey on economic models that analyze incentives for international environmental cooperation and by categorizing the different instruments proposed in the literature to support incentive compatibility. The survey does *not* claim to reflect the entire spectrum of the literature on transboundary environmental externalities.¹ For example, important aspects of international pollution control such as imperfect and/or incomplete information are treated only briefly. Moreover, all models discussed in this survey assume countries to be ‘unit actors’ whose governments maximize national welfare.² This survey focuses on the economic instruments that stimulate and sustain cooperation on the internalization of transboundary or even global environmental externalities.³ It is thus oriented towards contributions that explore possibilities to compensate for the fundamental lack of institutional structure on the international level.

Instruments to promote and stabilize international environmental cooperation generally influence both the incentives for participation and compliance. Some provisions even produce a conflict between cooperation incentives *ex ante* and *ex post*. There is thus no point in grouping conceivable strategies according to which type of incentives they affect. Instead, we classify the instruments according to how closely they are related to the environmental policies of the governments involved. Starting with the choice and design of the internalization instrument itself, we gradually enlarge the strategy space of the players (the national governments) and increase the complexity of the underlying decision problem to discuss the additional instruments that are possible in those contexts, respectively. The strategy space is expanded by adding the time dimension to the decision problem –i.e. by assuming repeated decisions on pollution abatement – and by allowing for compensations in various forms as an additional instrument variable. The underlying decision problem is extended to take into account utility

¹ Mäler (1990) provides a comprehensive taxonomy of international environmental externalities and an excellent introductory survey on important theoretical aspects of their internalization through international cooperation. For a brief overview see Carraro and Siniscalco (1992), for a policy-oriented survey Verbruggen and Jansen (1995).

² See chapter 4 of Schulze and Ursprung (1998) for a survey on the political economy of international environmental policy.

³ We do not consider arguments that call for an international coordination of policies even in the case of purely national environmental problems (see e.g. Hoel 1997; Kox and Tak 1996).

interdependencies (i.e. additional arguments in utility/welfare functions) and interdependencies with other markets (i.e. general equilibrium effects). Combinations of these extensions and the related instruments are certainly possible and realistic, but we discuss them separately for clarity of the argumentation.

Accordingly, the structure of the paper is as follows.⁴ In section 2 we discuss which influence the choice and shaping of the internalization instrument itself has on the incentives to engage in environmental cooperation. Section 3 enlarges the strategy set of the governments by the time dimension and considers treaty provisions that make future abatement efforts of observant parties dependent on the (potentially defecting) behavior of other countries. This way of warranting incentives for cooperation exploits the fact that environmental policy decisions are repeated and is referred to as *internal stabilization*. In section 4 the strategy space is expanded to comprise compensations and sanctions of various forms (monetary side payments, issue linkage, trade sanctions etc.) as additional instruments to provide cooperation incentives. They can be labeled *external stabilization* instruments as they are not necessarily restricted to cooperation on environmental externalities. Section 5 investigates how unilateral and accompanying measures by single countries or subcoalitions cohere with the incentives to participate in and comply with an environmental convention. These may be motivated by special preference structures (altruism, reputation, social norms etc.) or by general equilibrium effects of abatement activities. Finally, section 6 briefly addresses long-term measures in the form of flexible adjustments of an agreement to changed circumstances and of improved framework conditions for international negotiations. The survey concludes with a brief summary and an outlook on possible future research.

2 The choice of the internalization instrument

In general one can distinguish between policy instruments for the internalization of environmental externalities that are market-based and those of the command-and-control type. The former comprise emission taxes or tradable emission permits, the latter emission quotas, technology standards or other forms of direct regulation. It is a central result of the theory of

⁴ The structure of is inspired by Heister et al. (1995) who distinguish between internal and external stabilization instruments and flexible adjustments to an agreement.

environmental policy that an internalization by market-based instruments is the superior policy option as it guarantees the realization of a given environmental standard at lowest social costs. By contrast, uniform solutions like fixed quotas usually are (i) not cost-effective in a static sense, i.e. the same environmental effect could be achieved at lower social costs through a different distribution of abatement efforts across countries; (ii) they are inefficient in a dynamic sense because they do not create incentives to reduce emissions even further by investing in new and cleaner technologies. From the perspective of global efficiency, this holds for transboundary externalities as well. Yet in the context of voluntary cooperation the question arises which type of internalization instrument harmonizes best with the requirement of incentive compatibility, especially if international lump-sum transfers are not possible. In the following, we look first at explanations for the widespread use of uniform solutions and fixed quota agreements on the international level. Subsequently, we introduce the market-oriented instrument of *joint implementation* that is proposed as a supplementary element of a quota agreement in the context of climate policy. The section closes with a discussion of market-based instruments by comparing international emission taxes to tradable emission permits and by presenting some suggestions to increase the incentives to cooperate if these instruments are chosen in an agreement.

Up to now national governments have been very reluctant to implement market-based instruments for the internalization of environmental externalities. International environmental negotiations in most cases lead to uniform or inflexible solutions, e.g. in the form of equal percentage abatement obligations. If quotas are without doubt an inefficient instrument, why are they nevertheless the outcome of so many negotiations on international pollution control in reality? One can think of several reasons for the latter phenomenon:⁵ first, uniform solutions are apparently 'fair'.⁶ Moreover, negotiating complex differentiated solutions is associated with high transaction costs and manifold informational problems. Asymmetric information on the valuations of environmental quality and uncertainty about the working of the ecosystem make

⁵ It is known from the politic-economic analysis of command-and-control policies to reduce purely national pollution that quotas may create rents whereas taxes do not. This may be an important explanation also in an international context, but is disregarded here.

⁶ The aspect of equity and the impact of different principles of burden sharing, especially rules of equal sacrifice, on the incentives to sign a global climate treaty are discussed in Welsch (1992).

it often very difficult to determine economically efficient, differentiated strategies to internalize international environmental externalities.⁷ In addition, when there exist several potential agreements (i.e. multiple equilibria) simple rules as uniform quotas may serve as a ‘focal point’ during negotiations.

Whenever countries are heterogeneous and compensation payments are ruled out, there is a close relationship between the choice of the internalization instrument, the agreed international environmental standard and the incentives to cooperate (Barrett 1992). If asymmetric countries are assumed to negotiate on equal (percentage) reductions and the outcome is determined by the median country of the coalition, some but not all countries involved in the pollution problem will cooperate in equilibrium (Hoel 1992). The stricter the chosen environmental standard and the higher the requirements on incentive compatibility, the fewer countries will find it in their interest to participate in the agreement which, *ceteris paribus*, decreases the global level of pollution reduction.⁸

A partial cooperative solution not only emerges when the use of the quota instrument is exogenously given. The same result is derived e.g. by Finus and Rundshagen (1998) in an extended framework where the choice of the internalization instrument is endogenously determined, participation as well as compliance incentives are taken into account, and in which the preferences of the marginal signatory (instead of the median country of the coalition) are decisive for the outcome of the agreement. Moreover, a quota systematically dominates a uniform emission tax although the latter is (due to its cost-effectiveness property) preferable from a global perspective. However, from the perspective of the country that is the ‘bottleneck’ in the negotiations and decisive for the terms of the agreement – the country with the lowest environmental preferences – the quota is superior to the tax. In the quota regime all countries carry the same relative abatement burden, whereas under the tax regime the relative

⁷ Due to lack of space we do not discuss these problems in detail See e.g. Larson and Tobey (1994) for the role of uncertainty in global climate policy.

⁸ Correspondingly, in the case of only two asymmetric countries uniform emission reductions have to be set at sub-optimal levels for an international environmental agreement to exist at all (Endres 1993).

burden is the higher, the lower environmental preferences are.⁹ This corresponds to an analysis of Kverndokk (1993) suggesting that the poorest countries in the world would have the highest costs of reducing emissions relative to GDP when carbon emissions are allocated in a cost-effective way. Hence, although uniform quotas may considerably restrict the number of participating countries, the use of taxes or emission permits may be even a greater disincentive for many countries to sign an international environmental treaty. Especially when national governments have to compromise on ‘the smallest common denominator’ the quota instrument is likely to be chosen in an environmental agreement. Of course, these conclusions are only valid as long as international side payments, an international redistribution of tax revenues or an appropriate initial allocation of emission permits are not possible.

Given the multi-dimensionality of international economic relations there exists an additional argument not to pursue an environmental policy that would be optimal in a first-best world. This is shown by Mohr (1995) in a general equilibrium framework with overlapping generations where two countries are linked to each other not only by environmental externalities, but also via international debt. Although the countries may agree to implement an international tradable-permit scheme they will not necessarily trade emission permits in quantities such that marginal abatement costs are equalized across countries. If the debt steady state is constrained by country sovereignty (i.e. if the incentive compatibility constraint for the debtor country to comply with the debt contract is binding) the loans are not as high as in the scenario with full enforcement. Yet, if the debtor country is a net exporter of emission permits selling permits works as a substitute for the procurement of capital by international debts. Consequently, it may be in the interest of the creditor country to reduce its demand for emission permits below the cost-effective level, thereby ensuring that the supply of capital in the debtor country does not exceed the level where it pays off not to settle its debts. This is a second-best argument: as another market (the market for debt) is imperfect with respect to the enforcement of contracts on the international level it is not necessarily optimal to select the first-best instrument for the environmental problem. Market-based internalization instruments may not only be inferior with respect to the incentives they provide for environmental

⁹ Due to the functional specification of national abatement costs assumed by the authors, all countries will reduce their emissions to identical absolute quantities under the tax regime, whatever their abatement benefits are.

cooperation, but also may increase the imperfections in other markets such as international debt.¹⁰

The use of quotas in international environmental agreements may give rise to substantial cost-inefficiencies as countries generally differ with respect to many characteristics and thereby in marginal abatement costs. In order to avoid the cost-inefficiencies of uniform solutions to some extent, certain governments have pressed in international environmental negotiations for at least a limited possibility to trade emission rights internationally. The most prominent example for this attempt is the concept of „activities implemented jointly“ that has been put down in the *Framework Convention on Climate Change*. It stipulates that two (or more) parties to the convention have the right to implement emission abatement measures jointly if they find it in their interest. According to this provision contracting parties with relatively high marginal abatement costs can fulfill (part of) their abatement obligations in countries with low marginal abatement costs and get the realized abatement quantities (at least partially) credited. This implicitly introduces international transfer payments and is equivalent to a trading of emission rights: under ideal conditions the combination of a quota agreement and *joint implementation* would lead to international cost-effectiveness. It corresponds to the approach already proposed by Baumol and Oates (1971) of setting the global environmental standard first and then selecting instruments to achieve these targets at the least cost. Even if the possibilities for joint implementation projects are restricted by the terms of an agreement and even if search and monitoring costs are high, some authors (cf. Bohm 1994) regard it as a first step towards a future system of tradable emission permits. Under ideal conditions with perfect foresight and no transaction costs, there is economically no difference between joint implementation and emission permit trading. Yet the issue of incentive compatibility remains crucial also in the context of joint implementation. It remains unclear how to be able to create incentives for the engagement into joint implementation projects and for their successful execution if it was not possible to agree on a market-based internalization instrument in the first place. So far this aspect has not been sufficiently addressed in the discussion on joint implementation.

A comparison of emission taxes and tradable emission permits yields that they possess similar characteristics with respect to their influence on cooperation incentives. The differences

¹⁰ However, Mohr (1995) shows that the introduction of cross-default clauses allows for a full strategic stabilization of the permit scheme. See section 4 for this strategy.

between these market-based internalization instruments rather have to be seen in institutional aspects.¹¹ For example, they do not differ substantially from each other in the degree of national sovereignty that has to be delegated to a supranational institution for implementation, monitoring and administration. Moreover, the question of how to redistribute the tax revenue of a global carbon tax is equivalent to the question of how to allocate initial emission permits (and future assignments) to the individual countries. If there are no restrictions on the way tax revenues or initial permits can be allocated to individual countries, they may be designed to support the broad and lasting participation of countries that would otherwise abstain from cooperation. This is possible even if the international distribution of emission permits has to be based on simple rules, such as existing emissions ('grandfathering'), historic emissions, current GDP or national population size. The same holds for rules that determine the redistribution of tax revenues to the cooperating countries. Each of the above rules distributes the gains from environmental cooperation in favor of a specific group of countries. The 'grandfathering' of permits or an assignment according to current GDP generally favors the industrialized countries, whereas population size (equal per capita emission rights) or historic emissions as a base would benefit the developing countries and would be accompanied by substantial trade of permits between industrialized and developing countries.¹² An attempt to increase the broad acceptability of a tradable permits solution could be to mix different allocation rules by constructing a weighted average of different criteria, the weights being adjusted over time.¹³ In order to mediate between the differing interests of industrialized and developing countries Pearce (1990) proposes to start with a grandfathering regime, but with emission entitlements changing over time in a way so that rising permits of developing countries less than offset declining permits of industrialized countries. Cline (1992) expects that an agreement to shift the weights of such a rule over time towards the population rule would have the best chance of broad and lasting support. It is important to note that all of the above proposals amount to

¹¹ See e.g. Hoel (1997), p. 122–124, or Zhang and Folmer (1995) for a comparison of tradable carbon permits with an international carbon tax with regard to institutional and implementation aspects.

¹² A study by Kverndokk (1993) estimates payments to the developing countries in the order of 6% and 3% of GDP in the year 2000 from the USA and the other OECD countries, respectively.

¹³ See Zhang and Folmer (1995), p. 139, for a formal presentation. Additional instruments to provide cooperation incentives possible in a dynamic framework are discussed in detail in section 3.

granting more or less explicitly transfers to certain countries. In the preceding discussion on internalization instruments this option had been ruled out since it constitutes an instrument to provide cooperation incentives of its own and is treated in detail in section 4.

The discussion of the use of market-based and command-and-control instruments in international environmental agreements has shown that uniform solutions often generate greater incentives for international environmental cooperation. It has also elucidated that in the context of international environmental cooperation the distributional effects of potential internalization policies become predominant in comparison to their efficiency properties. This holds especially in a second-best world where international transfers are not possible (or only to a negligible extent). Moreover, suggestions on the choice and forming of internalization instruments have in common that they focus on increasing the incentives to participate in an environmental treaty and neglect or rather are unable to provide sufficient incentives to comply with the obligations each party has committed to.¹⁴ In order to cope with this time consistency problem additional instruments are required. One plausible road to enlarge the strategy space of governments is to extend the time horizon in environmental policy, i.e. by assuming repeated decisions on pollution abatement. If breaching an environmental treaty can be sanctioned through lower cooperative abatements in future periods, this ‘shadow of the future’ makes countries eventually comply with their obligations. This strategy is discussed in the subsequent section.

3 Internal stabilization

Cooperating countries can exploit the fact that environmental policy measures are repeatedly taken. They can agree to sanction unilateral non-compliance with less ambitious internalization efforts in future periods. This obliges an opportunistic government to weigh the gains from unilaterally breaching the agreement against the future losses from being sanctioned. The purpose of such a strategy is to provide sufficient incentives to comply with a treaty in cases where the recourse to a supranational enforcement authority or to other stabilization instruments is not possible. The latter is presumed in the present section. Since the incentives

¹⁴ See Laffont and Tirole (1996) for an analysis of the impact of spot and future markets for tradable pollution permits on the potential polluters' compliance and investment decisions.

to cooperate are provided in terms of abatements – which are the actual issue of an environmental treaty – we refer to this strategy as *internal stabilization* (see also Heister et al. 1995). It corresponds to the principle of ‘reciprocity’ in international law. In order to be an effective threat the reactions to a breach of the treaty have to be both predictable and credible.

Dynamic games of international pollution control can be divided into models where identical decision-problems are repeated (supergames) and models in which not only current emissions matter, but where depositions accumulate over time, thereby generating *stock externalities*. In differential games with stock pollutants it can be shown that the globally efficient (full cooperative) allocation of abatements can be implemented as a sub-game perfect Nash equilibrium as long as the future is not discounted too heavily. This holds for *open-loop* as well as for *closed-loop* strategies and corresponds to the folk theorem. Closed-loop strategies take into account that the payoff and strategy space change over time in a differential game, whereas open-loop strategies only make use of information on the initial state. As a country – when observing emission levels that do not correspond to broad cooperation – terminates its own cooperation this strategy is very similar to trigger strategies in repeated (super)games. In the long run, the periodical emissions in a cooperative and in the open-loop non-cooperative equilibrium will be the same. However, the convergence towards the efficient level is faster with cooperative strategies, resulting in a lower stock of externalities (cf. Mäler 1991).¹⁵

Decisions about contributing to an international environmental good often resemble a repeated *prisoners' dilemma* type of game.¹⁶ In case of such an incentive structure global efficiency can be sustained as a cooperative equilibrium as long as the future is not discounted too heavily. This holds for the infinitely repeated prisoners' dilemma (folk theorem), but under additional assumptions and for a subset of rounds also for the finitely repeated prisoners' dilemma (cf.

¹⁵ The subsequent exposition concentrates on models with flow pollutants. For the analysis of transboundary stock pollutants see e.g. van der Ploeg and de Zeeuw (1991,1992), van der Ploeg and Ligthart (1994) or Kverndokk (1994).

¹⁶ For a different view see Heal (1994) who considers technological spillovers and fixed costs of abatement policies that have reinforcing effects on the formation of a *minimum critical coalition* in an international environmental agreement. The above assumptions imply a coordination problem in addition to the free-rider problem.

Kreps et al. 1982). In both cases cooperation is sustained by the threat to abort cooperation if one party does not stick to the cooperative strategy. One can distinguish different types of strategies according to how severe the sanctions are.

The most drastic form of internal stabilization is the *trigger* or *grim* strategy. It implies a return to non-cooperation once and for all if one country unilaterally defects. This is a very strong punishment which effectively deters free-riding behavior as long as renegotiations are ruled out. By contrast, if countries can renegotiate a new agreement after the breakdown of the initial one, announcing a grim strategy is not a credible threat: the sanctioning countries obviously harm themselves when returning to non-cooperation forever. In addition, it may be technically not possible or economically too costly to return to non-cooperative emission levels. Hence, to be of practical use trigger strategies must be both effective and credible.

To fulfill the credibility requirement countries may agree to *re-optimize* their cooperative abatement efforts after a breach of the international environmental treaty has occurred. The basic mechanism of this strategy is illustrated by Barrett (1994) both for a one-shot and an infinitely repeated game.¹⁷ In a model of N identical countries suffering from a global environmental bad, a cooperating countries are assumed to act as a Stackelberg leader and to maximize their joint net benefits of abatements. As joint net benefits depend on the size of the coalition, cooperative abatements are re-adjusted when a country joins or leaves the coalition. A unilateral breach of the agreement by a single country induces smaller cooperative abatements which works as a sanction against the disloyal country. This sanction is credible because it is the outcome of maximizing the coalition's welfare. Joining the coalition is individually profitable because a new member benefits from additional abatements of the other cooperating countries. On the other hand, each new member increases the incentive to take a free ride on cooperative abatements and to abstain from or leave the agreement. Consequently, the number of countries that cooperate remains limited. Barrett shows that a coalition of more than three countries is only stable when marginal abatement benefits decrease with global abatement quantities, implying non-orthogonal best response functions. In general, a stable coalition with many countries only emerges if the difference in global net benefits between full cooperation and the non-cooperative Nash equilibrium is small, i.e. if there is not much to gain

¹⁷ The one-shot game mirrors a dynamic structure of the decision problem as well, but assumes for simplicity that actions are immediately followed by reactions.

from cooperation; if there are large potential gains from cooperation only very small coalitions of at most three countries are stable, whatever the total number of countries involved in the externality.¹⁸ Besides the limited success of the re-optimization strategy the model does not solve the problem which of the N identical countries do cooperate and which do not.¹⁹ Moreover, as a defection by one country would induce entry by another, an effective re-optimization strategy requires that the coalition turns back new members and credibly commits to a sub-optimal size. The weakness of the stabilization strategy also remains in the context of a supergame with renegotiation proofness as stability concept. Although the full cooperative outcome can in principle be sustained as a sub-game perfect equilibrium of the infinitely repeated game for sufficiently small rates of discount, the sanctions that guarantee incentive compatibility may be vulnerable to renegotiation.

A stabilization strategy that avoids the incentive to renegotiate is *modified tit-for-tat*: countries cooperate until one of them defects and then exclude this country and readjust emissions according to the readjustment strategy described above. In addition, they do not readmit the defecting country before it has paid damages or has made a front end abatement concession. The latter serves to compensate the countries in the coalition for the losses they incur by executing the punishment, thereby making the threat of their execution credible. The defecting country will pass under the yoke if it can expect sufficiently high gains later in the future after all countries have returned to environmental cooperation. Hence, the above punishment strategy eliminates the gains from non-compliance without inducing the observant parties to renegotiate with the defecting government. This kind of 'stick-carrot' strategy is used in a model of Finus and Rundshagen (1998) where asymmetric countries form a coalition to cooperate on abatement efforts that constitute a global public bad. It is shown that international environmental agreements stabilized in this way can reap only small aggregate gains from cooperation if the externality problem is most severe, that is, if many countries

¹⁸ Coalition stability is defined here by using the concept of D'Aspremont and Gabszewicz (1986) and Donsimoni et al. (1986) for cartel stability in an oligopoly. In that literature similar results are derived with respect to coalition size.

¹⁹ The above coordination problem could be resolved by introducing asymmetries between the countries, e.g. in their relative bargaining power (see e.g. Barrett 1997a, Schmidt 1997).

suffer from transboundary pollution and if abatement is relatively costly compared to perceived environmental damages. In these cases only small subcoalitions prove to be stable.

Black et al. (1993) analyze a *minimum ratification clause* as an instrument to create incentives for environmental cooperation. It prescribes that the environmental convention does not come into force until a specified number of countries has ratified it.²⁰ In this case a single government not only takes into account the effects his own participation or abstention will have on the terms of the agreement, but also the possibility that there will be no cooperation at all in case of its own abstention. Due to incomplete information on the net benefits of environmental protection it is risky to abstain from the uncertain outcome of the ratification process. This risk must be balanced against the expected free-rider benefits. Although this instrument provides for participation incentives, it hinges on the assumption that countries do not renegotiate after having failed to reach a minimum number of signatories. Moreover, by assuming that the signatories remain committed to their obligations after the convention has come into force the problem of reduced compliance incentives is disregarded. In fact, the more successful the minimum ratification clause is in making a large number of countries sign the agreement, the greater the incentives to breach it afterwards. Thus this instrument generates a conflict between the provision of participation and compliance incentives.

To summarize, internal stabilization strategies are only to a limited extent apt to generate participation and compliance incentives for international environmental cooperation. It is true that there are better options to stabilize cooperation when the strategy space is extended by the time dimension and environmental policy decisions are modeled as a supergame. However, the requirements for such strategies to be successful are strict and are often not fulfilled under real world conditions. The weight that is put on future benefits – expressed by the discount rate – is crucial for all internal stabilization strategies. The more national welfare in future periods is discounted, the less effective is a stabilization through retaliation in terms of lower future abatement efforts. Imperfect observability of the countries' real internalization efforts and time-lags in the implementation of sanctions are additionally detrimental to internal stabilization. Finally, a retaliation by adjusting emissions to arbitrary levels may be technically not possible or

²⁰ As other forms of 'internal stabilization', minimum ratification clauses makes national abatement efforts contingent on the cooperative behavior of other countries. The distinctive feature of such clauses is that they represent a sanction for non-cooperation even before the treaty has come into force.

economically too expensive. New and environmentally friendlier technologies being developed and applied in the course of international environmental cooperation may not be easily replaceable anymore.²¹ Hence, international environmental agreements have to rely on additional stabilization instruments. These are discussed in the next section.

4 External stabilization

Instruments for an external stabilization of international environmental agreements are measures that modify the pay-off of the players in other ways than by the pollution reduction activities themselves. They may be used to warrant incentives for compliance as well as participation and can be implemented in various ways. The two basic forms are transfers and sanctions that are stipulated in an environmental convention and executed according to its terms. Both instruments enhance the incentives for cooperation, but in different ways: while sanctions reduce the individual gains from breaching an agreement, transfers redistribute the gains from cooperation in a way that increases cooperation incentives for certain critical countries. Correspondingly, transfers will always, sanctions never be executed in an incentive compatible agreement (provided that there are no unforeseen changes to exogenous circumstances). Hence, (utility) transfers and sanctions are basically dual approaches to create incentives for cooperation: an agreed transfer not given to a country because of its non-cooperation represents a sanction for defecting behavior.

We start the discussion of external stabilization instruments with a survey on contributions that analyze the general profitability of compensation schemes (subsection 4.1). Subsequently, various forms of transfers and other external stabilization instruments are presented. As will become clear a strict distinction is often not possible. Nevertheless we will devote separate subsections to 'issue linkage' (subsection 4.2) and trade sanctions (subsection 4.3) because these instruments are discussed the most in the literature. The section concludes with an evaluation of external stabilization for the incentive compatibility of international environmental agreements (subsection 4.4).

²¹ See e.g. Carraro and Siniscalco (1993), fn. 3, for this objection.

4.1 Transfers

International compensations are an important instrument in international environmental cooperation. Their basic purpose is to redistribute the gains and burdens from a cooperative solution in a way that makes it attractive to many – if not all – countries to join an environmental agreement. In an early contribution Markusen (1975) has shown that in face of a transboundary environmental externality international transfers are in general a necessary and sufficient condition for a cooperative solution that yields a Pareto-optimal allocation of world resources. In contrast, without transfer payments international environmental cooperation will generally not result in global efficiency, even if one assumes that countries can make binding commitments. The reason is that in these cases the cooperative solution depends on the characteristics of the countries involved in transboundary pollution as e.g. their initial endowments with resources. The only way to install broad cooperation without additional compensations then is the recourse to a less ambitious treaty that does not correspond to the full cooperative solution (see section 2).

By applying the concept of the core of cooperative game theory to transboundary pollution problems, Chander and Tulkens (1997) show that under plausible assumptions concerning the behavior of governments not belonging to a coalition the related γ -core of the game is non-empty. They analyze a scheme of cooperative abatements and appropriate transfers which guarantees the profitability of the agreement to all countries involved in the externality so that a globally efficient outcome can be sustained.²² This mechanism bases the burden-sharing on the relative intensities of the countries' environmental preferences. In this respect the proposed cooperative solution is similar to the ratio and Lindahl equilibria in economies with public goods. It is strategically stable in the sense that it is able to provide participation incentives.²³ A similar approach is used by Eyckmans (1997) who analyzes a *proportional cost sharing* mechanism that distributes total costs of emission reductions in proportion to the participants' marginal willingness to pay for the international environmental good. The proposed mechanism is shown to have the following properties: Firstly, it yields an efficient (i.e. cost-effective)

²² See also Chander and Tulkens (1995) for the merits of transfers in a cooperative game of international pollution control.

allocation of abatements. Secondly, its proportionality is widely accepted as a form of fairness in international negotiations. It reflects the idea that countries which benefit more from environmental quality should bear a larger share of the burden, similar to the Lindahl solution of how to share the burden of a pure public good. Thirdly, the resulting coalition yields an allocation in the α -core of the cost sharing game. Finally, proportional cost sharing can be implemented as a Nash equilibrium under complete information with the help of a simple tax/subsidy mechanism.

The adoption of a burden-sharing scheme is a general problem when the cooperating countries are heterogeneous. As the burden-sharing will be anticipated by governments that consider to join a coalition, different cooperative solutions may emerge depending on the adopted scheme. In a numerical simulation analysis calibrated to a data set with five world regions Botteon and Carraro (1997) compare the outcome of negotiations under burden-sharing based on the Nash bargaining concept with the one based on Shapley values.²⁴ According to the simulations the latter concept seems to be preferable in an agreement that uses transfers to expand a coalition. The reason is that burden-sharing according to the Shapley value provides cooperating countries with a more even distribution of the gains from cooperation. This observation points again to the importance of distributional in comparison to efficiency aspects in international environmental negotiations, as was emphasized already in section 2. The policy implications of this analysis though remain somewhat unclear because the adopted burden-sharing rule depends on the given relative bargaining powers of the governments; and the latter have only their national welfare position in mind when negotiating an agreement.

The above contributions have in common that they apply cooperative game theory to the problem of coordinating environmental policies. Although the results derived in this framework certainly deliver valuable insights into potential cooperative solutions, in a cooperative game the players are taken to be able to engage in binding commitments, an assumption that does not correspond to the lack of enforcement on the international level. On the other hand, the nonexistence of a supranational enforcement authority does not imply the absence of any institutional framework on the international level. This, however, is implicitly assumed when

²³ Within the wider context of differential games assuming stock externalities, Germain et al. (1997) observe that the said attractiveness of the transfer scheme is maintained.

²⁴ In an analysis of heterogeneous countries Barrett (1997a) employs the Shapley value as well.

modeling the strategic interactions of sovereign states as a non-cooperative game. In the latter framework agreements have to be fully self-enforcing and cooperative solutions without transfers or other additional instruments consist of small subcoalitions that achieve only little.²⁵ In contrast to the extreme assumptions on enforceability of non-cooperative and cooperative game theory, the existence and widespread use of international environmental institutions suggests to introduce a limited degree of enforcement in the theoretic analysis, for example by assuming that binding commitments are possible for certain groups of countries (cf. Carraro and Siniscalco 1993; Hoel 1994), and to analyze the use of side payments within this framework.

Transfers are an important instrument to make countries not only sign, but also comply with an international environmental agreement. This is shown for the case of identical countries by Carraro and Siniscalco (1993) who consider a one-shot abatement game of complete information where cooperating countries induce the accession of additional countries to the coalition by giving self-financed transfers, i.e. side payments that are financed out of the former coalition's gains from enlarging the number of cooperating countries. To sustain broader coalitions by means of transfers it is necessary, however, to introduce a minimum degree of commitment into the game. This means that at least some players cannot deviate from the cooperative strategy they have voluntarily agreed on and it implies that the agreement is not fully self-enforcing.²⁶ Carraro and Siniscalco (1993) analyze different forms of commitment that – although limited and less demanding than full commitment by all governments – under certain conditions can even lead to a stable ‘grand coalition’. The achievable gains from cooperation depend strongly on what kind of commitment exactly is assumed²⁷ and on

²⁵ In most cases coalitions involving more than three countries are not stable. This result is quite robust with regard to different assumptions on countries' welfare functions (see e.g. Barrett 1994, Carraro and Siniscalco 1993, Hoel 1991,1992).

²⁶ In the scenario of identical countries the new, enlarged coalition would otherwise not be stable as paying transfers reduces the interest of the donor countries in the agreement.

²⁷ For example, if the group of countries that are pre-committed to cooperation is endogenously determined, the anticipation of receiving transfers reduces the incentive to sign an IEA and to commit to cooperation. In a model of identical countries where social norms influence a national government's participation decision, Hoel and Schneider (1997) show that total emissions may be even higher with side payments than without.

additional assumptions concerning the costs and benefits of pollution abatements. The latter remain undetermined in the above analysis.

Self-financed transfers can reap even greater gains from stable cooperation if the countries involved in the coalition formation process are heterogeneous. In such cases some countries may not possess incentives for free-riding, but incur a welfare loss from environmental cooperation. Yet for a preexisting coalition the entry of such countries is often profitable because it can help to reach a negotiated environmental standard at lower costs. Side payments then are the only way to create participation incentives for these low cost countries and to generate additional gains through internationally cost-effective cooperative abatement policies (cf. Hoel 1994, Kverndokk 1993).²⁸ Petrakis and Xepapadeas (1996) show with a model of heterogeneous countries that even the global first-best optimum can be implemented as a cooperative solution through appropriate self-financed transfers to initial ‘outsiders’. This result corresponds to the analysis of identical countries in Carraro and Siniscalco (1993) and is possible as long as (i) a subgroup of countries (the donor countries) is committed to cooperation, (ii) this group maximizes global welfare, and (iii) the marginal pollution damages of the recipient countries are not too high.²⁹

Schmidt (1997) shows that substantial gains from environmental cooperation are possible even if self-financed transfers are restricted to compensate countries with low marginal abatement costs for their incremental costs of increasing abatements to cost-effective levels. The transfers are the higher, the greater the initial cost-inefficiencies in the non-cooperative equilibrium are, and are used as an instrument to enforce the agreement. Therefore, the enforceable welfare gains from stable cooperation increase with the heterogeneity of the countries. Again a minimum degree of commitment is required to render the cooperative solution stable. Instead

²⁸ A numerical study of Kverndokk (1994) calculates the gains from expanding an existing subcoalition that is committed to a joint carbon emission abatement policy (analogous to the scenario of *internal commitment* in Carraro and Siniscalco 1993) by compensating countries outside the coalition for the losses they incur from not emitting non-cooperative quantities. Even if cooperation is only partial, the simulations show that substantial gains are attainable.

²⁹ Furthermore, Petrakis and Xepapadeas (1996) develop a mechanism to enforce a cooperative solution even if monitoring is difficult in the sense that information on global emissions is public, but information on national emission quantities is not. By this mechanism, every country has an incentive to report its true emissions.

of assuming binding commitments for a subgroup of the players it is introduced a 'third party' (e.g. an international agency) where side payments are deposited before given to the recipient country. This allows to analyze how credible commitments of sovereign countries can be achieved and to illustrate the usefulness of particular international institutions. Together with sequential moves of the parties in the implementation of the agreement, this game structure solves the time consistency problem also without assuming commitment by the donor countries. The results demonstrate that substantial gains from international environmental cooperation are enforceable if existing institutions are properly used.

A related instrument to transfers employed in the above manner is to deposit securities at a third party that are definitely lost for a country breaching the environmental treaty. The deposition of securities without the recourse to a third party can be accomplished by exchanging 'hostages' or 'pledges' (cf. Williamson 1983). Hostages are of value only for the depositing country, pledges also for the country that can dispose of it in case the depositing country has breached the contract. The more valuable the securities the higher are the cooperation gains that can be secured. The exclusive purpose of deposits is to enable credible commitments. In contrast, transfers are paid to create positive cooperation incentives and additionally are deposited to secure compliance. If an environmental agreement includes side payments and a trustee is available it may thus be easier to agree on depositing these transfers instead of additional securities of substantial value. The deposition of securities or transfers at an international agency can generate additional compliance incentives if the agreement provides that the retained deposits of defaulting countries are used to compensate observant countries for their costs of additionally sanctioning a non-compliant country, thereby making these additional sanctions credible (Heister et al. 1995, p. 38).

We now turn to the various ways in which welfare transfers between countries are conceivable.³⁰ The most straightforward form are monetary transfers flowing either directly from a donor to a recipient country or being granted by a common fund of the donor countries. Unfortunately, the fungible character of cash creates incentives for opportunistic behavior if a strict appropriation of compensation payments for their purpose cannot be guaranteed. The risk that received monetary transfers are not used for the purpose they were granted for is

³⁰ The contributions discussed so far treat side payments as *utility* or *welfare* transfers and abstract from the way in which they are executed.

present also in the context of an agreement on internationally tradable carbon emission permits (cf. Mohr 1991,1995). A breach of the contract in the case of an international permit market may occur if a (developing) country sells its excess permits and uses the revenues to boost its economic growth, thereby expanding CO₂ emissions as well. Once the country has sold all its excess permits it loses interest in complying with the agreement and starts to emit without possessing the corresponding permits. Such an opportunistic country may even borrow against the future income from (leased) permits and breach the contract later. A similar risk is given in case of agreements that provide side payments to certain countries in the present and grant a grace period of emission abatement obligations for the same group of countries, as it is the case in the Montreal Protocol on substances that deplete the ozone layer.

In order to circumvent the disadvantages of monetary transfers national governments may resort to *in-kind* transfers. The latter cannot be used for other purposes than the one they are granted for without incurring retrading costs. If these costs cover the value of the in-kind transfer completely the incentives for opportunistic behavior are entirely eliminated. Hence, in-kind transfers are a superior instrument in situations where institutional arrangements to rule out the abuse of side payments are not available (cf. Stähler 1992). The concept of 'joint implementation' stipulated in the *Framework Convention on Climate Change* makes use of this idea in the sense that it allows countries to reduce CO₂ emissions by replacing 'dirty' by 'clean' energy technologies abroad, i.e. in recipient countries. A similar argument holds for compensations given to the development and use of environmentally friendly, irreversible technologies that do not allow to increase emissions again after the new technology has been implemented. By paying for the introduction of a 'clean' but capital intensive technology, for example, a switch to yet another technology (or back to the old, 'dirty' one) may become prohibitively expensive, thereby generating a ratchet effect that secures compliant behavior of recipient countries. Stähler (1993) shows that transfers for 'irreversible' abatement technologies provide commitment options which render these technologies superior even if they are more costly than alternative reversible technologies. This form of transfer is the more attractive the less the recipient country takes into account the future impact of the irreversibility. A low valuation of the future favors the donor because it decreases the component of the transfer that compensates the recipient for being locked into an irreversible technology.

4.2 Issue linkage

The linkage of different and otherwise independent issues in international negotiations is another way to engage in international compensations. In a second-best world where monetary transfers between countries are not possible, issue linkage may work as a substitute and allow for cooperative solutions where isolated agreements would not emerge.³¹ By concessions in other policy fields that are on the agenda at international negotiations, e.g. other international environmental problems, trade policy, international debt, development assistance or the membership in a military alliance, it is possible to alter the pay-off structure of the countries in a way that makes the participation in an international environmental agreement profitable. Issue linkage may thus imply an implicit transfer between countries. Accordingly, the withdrawal of existing international privileges can be used as a sanction in order to provide compliance incentives.

Cesar and de Zeeuw (1996) analyze issue linkage across two reciprocal environmental externalities within the framework of a dynamic bi-matrix game. For each of the two externalities, both countries are simultaneously polluters and polluted, but national costs and benefits of abatement efforts are distributed asymmetrically across countries so that one country is worse off under isolated cooperation in comparison to mutual non-cooperation as long as it is not compensated in some way. Depending on the pay-off structure the initial situation can be characterized either as an asymmetric prisoners' dilemma or a *suasion game*. In the former game both countries have an interest in the negotiated issue whereas in the latter only one country is interested.³² For both games cooperation can be sustained if the games are infinitely repeated and the values of the discount rates are small enough. However, without side payments the cooperative equilibrium will not support global efficiency. Assuming a second game that represents the exact mirror image of the game described above Cesar and de Zeeuw (1996) show that by linking the two offsetting pollution games the social optimum

³¹ For the merits of issue linkage from a global point of view and general conditions under which Pareto optimality emerges see Carraro and Siniscalco (1995).

³² In the two-player suasion game the pay-off structure is such that non-cooperative behavior is the dominant strategy for one player, but cooperation dominant for the other. Thus, in contrast to the prisoners' dilemma in the non-cooperative Nash equilibrium of the suasion game one player behaves cooperatively and the other does not.

can be sustained with renegotiation-proof trigger strategies where non-compliance of a country in one agreement can be credibly punished by suspension of cooperation on the other issue.

Folmer et al. (1993) illustrate the linkage of an environmental with a non-environmental issue within the approach of an *interconnected game*. They consider an example with two repeated prisoners' dilemma games: a pollution game with a unidirectional transboundary externality and a trade game. It is shown that playing the two games independently results in cooperation only if (i) the games are repeated infinitely, (ii) the discount factor is not too low so that trigger strategies are successful and (iii) if one allows for (monetary) side payments. The resulting aggregate pay-off is lower than in the case where the two games are strategically linked to each other. The model demonstrates that issue linkage is especially attractive when countries are strongly asymmetric regarding their perceived damage from transboundary pollution and monetary transfers are not available. This is most obvious for the case of a unilateral externality, a scenario that naturally calls for a compensation payment. Issue linkage in this model is optimal even if international transfers are feasible. This superiority of issue linkage in comparison to a cooperative solution with financial transfers, however, hinges on the assumption that offering a transfer implies a loss in terms of being labeled as a 'weak negotiator', i.e. damages in reputation.

Carraro and Siniscalco (1997) analyze the linkage of negotiations on an environmental agreement and on technological cooperation by identical countries. In their model environmental coalitions are profitable but unstable, whereas coalitions that cooperate on R&D are both profitable and stable. Linking the two issues increases the number of countries that participate in a stable environmental coalition because the gains from R&D cooperation offset the environmental free-riding incentives. This is shown by using a specific functional form for the pay-off of each country and firm. The decision process consists of three stages: in the first stage individual countries decide on participating in the linked agreement and a stable coalition is formed; in the second stage optimal abatement levels of cooperating and non-cooperating countries are determined and in the last stage the firms in all countries choose their profit-maximizing output levels and expenditures on R&D. Technological spillovers are modeled as an excludable positive externality between firms in different countries.³³ It is assumed that

³³ This approach resembles the idea put forward most prominently by Olson (1965) to make the access to an excludable club good dependent on the individuals' contributions to the supply of a non-excludable

innovation spillovers are always larger between countries that belong to the coalition than between outsiders. This assumption is debatable because countries may cooperate on R&D activities independently from environmental cooperation. It is not clear why the latter spillovers should be smaller, at least as long as research activities are not connected in some specific manner with environmental policy. For example, if there are economies of scale in R&D cooperation, these may be realized not only by a coalition that simultaneously cooperates on environmental protection, but also by a sufficiently large coalition of outsider countries. In general, issue linkage is more of relevance when countries are asymmetric. For in that case they have differing interests in the various topics dealt with in international negotiations. Issue linkage then is a bargain on concessions in different policy fields between countries, leading to some kind of ‘package deal’.

Mohr and Thomas (1998) analyze the prospects of resolving the enforcement problem by issue linkage in the context of international debt and in the presence of uncertainty.³⁴ In their model they consider the simultaneous existence of an international environmental agreement between a state and a multilateral (or foreign) environmental agency and an existing international debt contract between the same state and a foreign lender, both of them burdened by lack of enforcement: The compliance problem in environmental agreements corresponds to the repayment risk for lenders in international loan contracts and the expropriation risk for direct investments. Uncertainty is given through an exogenous random cost to the country of violating any of the two contracts. It is shown that compliance with both of the two contracts can be guaranteed by a *cross-default* contract between the environmental agency and the lender so that the government cannot discriminate between complying with the debt and the environmental treaty. Cross-default clauses are often used to stabilize international debt relations. Instead of being a contract between several creditors, here the idea is to pool risks between parties that have different relations with the sovereign. The pooling of sovereignty risks additionally creates incentives to engage in *debt-for-nature swaps* that would otherwise

public good. For instance in the case of labor unions membership is rewarded with extra benefits that are excludable to non-members.

³⁴ See Mohr (1995) for the strategic linkage of international debt and pollution permit trade in the absence of uncertainties.

not exist.³⁵ Induced swaps provide additional gains for the agency and the lender so that both may accept some loss in terms of higher risk from the cross-default contract. However, several limitations exist with respect to the pooling of sovereignty risks.³⁶ Firstly, both the creditors and the environmental agency must have an incentive to agree on pooling compliance risks. This is given in some but not all risk constellations where the risks are not too different and too extreme. Secondly, the effect of the cross-default contract on the country's welfare position is indeterminate. Thus, the environmental treaty may have to include a clause which allows the pooling of sovereignty risks also without the consent of the sovereign. Finally, successful risk pooling requires the execution of the cross-default clause itself to be incentive compatible *ex post*. If the compliance risk was uniformly present for all kinds of contracts, the risk pooling strategy would not be effective. Yet in many cases it may be possible to protect cross-default clauses from the compliance problem by a contracting of the parties under their national law which is fully enforceable. The advantage of stabilizing environmental treaties in the above manner is that the long-term compliance problem governments face is delegated to the private sector. In contrast to national governments, private firms or institutions are able to engage in binding commitments because they are subject to national law enforcement.³⁷

4.3 Trade sanctions

The discussion of cross-default clauses has illustrated that the threat to withdraw some existing advantage or to terminate cooperation in another policy field is a special form of issue linkage. The difference to the previously approaches is that they represent a sanction instead of a transfer (in terms of national welfare). The most prominent and widely discussed form of sanctions are trade restrictions as retaliation measure against non-cooperative behavior on the

³⁵ A debt-for-nature swap is a trade where a reduction in a country's debt is granted for additional environmental policy measures this country undertakes.

³⁶ See also Kirchgässner and Mohr (1996), sect. 4.2, on problems of cross-default clauses.

³⁷ Of course, this requires the existence of an international agency or other independent party to engage in cross-default contracts.

international level. Like cross-default clauses they are often stipulated in the environmental treaty so that they can be properly anticipated.³⁸

The potential of trade sanctions for stable environmental cooperation is analyzed by Barrett (1997b) in a partial equilibrium model with homogeneous countries and intra-industry trade. It is assumed that imperfectly competitive firms produce an identical output but segment their markets. Trade sanctions are used to enforce the cooperative supply of a global public environmental good. The threat to exclude countries from trade that do not cooperate on international pollution control is credible because the sanctioning countries gain from executing the sanction via increased firm profits. The decisions of firms and governments are modeled in a game of several stages: At first governments decide whether a potential environmental treaty should employ trade sanctions and if yes under what conditions; then countries choose simultaneously to become a signatory or non-signatory to the agreement; in the third and fourth stage respectively, signatories and non-signatories determine their abatement standards; in the final stage firms choose their segmented outputs according to Cournot-Nash behavior. Governments that do not cooperate take the abatement standards of other countries as given, cooperating countries are assumed to maximize their collective welfare.³⁹ By taking out numerical simulations for agreements with and without trade sanctions it is shown that in many (but not all) cases an agreement with trade sanctions is preferred and that even the social optimum can be sustained. The latter outcome additionally requires the introduction of a minimum participation level to secure coordination on the full cooperative solution. Unfortunately, an intuitive explanation is not given how the execution of trade sanctions is made incentive compatible also *ex post*, once a violation of the agreement by a single country has occurred. Moreover, the results of the analysis need to be considered carefully due to the specific set-up.

³⁸ The general influence of uncertainty and reputation on the effectiveness of sanctions as a stabilization device is discussed by Heister et al. (1995).

³⁹ This is not problematic since countries are assumed to be identical and the question how to distribute the gains from cooperation does not arise.

Also without the above stabilization strategy global environmental policy will typically be linked to international trade policy.⁴⁰ One reason is the ‘leakage’ phenomenon which cooperating countries can try to curb by imposing appropriate tax and tariff adjustments.⁴¹ Another potential cause are problems to implement regulatory measures directly in cooperating countries in which the externality-generating activity takes place. These can be administrative difficulties or lack of enforcement already on the national level, especially in developing countries. Trade policy measures then principally can serve as a second-best instrument for international pollution control. Of course, trade restrictions often also serve protectionist purposes. It can be argued, though, that the political support for trade restrictions can turn into an advantage in the sense that it increases the credibility of this instrument (cf. Kirchgässner and Mohr 1996, p. 210–213). Nevertheless, multilateral trading rules should not permit parties to an (environmental) agreement to impose arbitrary trade restrictions because they tackle the problem of internalizing transboundary externalities only indirectly and may be a catalyst for protectionist policies. Moreover, the causes for non-compliance sometimes do not lie in deliberate, but in endemic and erratic decisions. This weakens the justification of strict sanction schemes to a certain degree.

4.4 Evaluation

Taken together, the above discussion shows that trade policy measures can indeed contribute to achieve mutual gains from environmental cooperation, at least in the context of ‘issue linkage’. This is the case especially when the welfare-improving removal of existing trade restrictions is used as a carrot to make countries participate in and comply with international environmental agreements. The general advantage of linking different policy issues consists in its ability to provide participation and compliance incentives for a package deal in cases where isolated agreements would not emerge or not prove to be stable. On the other hand, linking previously unrelated topics in international negotiations may go along with substantial negotiation (and other transaction) costs. For example, a complication arises when the issues to be linked in an international environmental agreement are already regulated by international

⁴⁰ See Kirchgässner and Mohr (1996) for a general discussion of the effectiveness, efficiency and credibility of trade restrictions to promote international environmental policy.

⁴¹ See section 5 for a sketch of this problem.

law as in the case of trade policy and the rules of the WTO. In addition, the strategy to substitute many isolated compliance risks by only a few bundled risks may create the danger of a deep crisis in international politics, once a contract violation for whatever (accidental) reason has occurred.

The crucial precondition for the applicability of sanction schemes to sustain international environmental cooperation is their credibility. After a unilateral breach of an environmental convention it must not be rational for the observant parties to continue cooperation with the defecting country nevertheless. Given that sanctions in most cases will be costly for the punishing country as well, it is not an easy task to fulfill the credibility requirement. This is one major aspect in which sanctions differ from transfers. Self-financed transfers are credible by definition.⁴² The basic advantage of external stabilization by transfers is that it allows for a separation of national abatement efforts from related economic burdens. Thereby, larger and stable coalitions with a more efficient distribution of abatement activities across countries are attainable, resulting in a higher degree of internalization of transboundary environmental externalities.

Even if feasible, transfers have a number of limitations for the stabilization of international environmental agreements as well. Side payments may give rise to inefficiencies in as far as they are given by downstream countries to bribe polluting countries to internalize these externalities. For in this case they imply the application of the *victim pays principle* rather than the *polluter pays principle* ('PPP').⁴³ Although the distribution of property rights makes no difference for global efficiency in a static framework, the 'PPP' is preferable from a dynamic perspective because it creates appropriate incentives for innovations in abatement technologies (see e.g. Mäler 1990, p. 82). It is true that the polluter pays principle has been adopted by various agreements for domestic implementation by national environmental policy, but its application on the international level is unrealistic given the status quo in which each sovereign state claims for itself the right to pollute. Moreover, countries that are less concerned about environmental quality and thus potential recipients of side payments may reduce their own

⁴² Of course, this requires that donor countries can credibly commit themselves on the *execution* of transfers, an aspect often neglected in the literature.

⁴³ Issue linkage represents an implicit transfer from polluted to polluting countries and implies the application of the victim pays principle, the payment being made in these cases not in cash but in kind.

abatement efforts below non-cooperative levels or even stop abatement altogether if the cooperative measures they are compensated for are sufficient to satisfy their own lower preferences. In such cases strategic behavior will lead to a *crowding out* of cooperative and non-cooperative abatement efforts (see e.g. Mäler 1990, p. 99). Especially when abatement technologies can be politically influenced (i.e. in the long run), it is difficult to determine the hypothetical scenario that would have been realized without any agreement. In many cases the anticipation of agreements creates incentives for pre-negotiation behavior that is detrimental to environmental protection. For example, it may be a rational strategy from the point of view of a national government that anticipates an international environmental agreement to choose deliberately a ‘dirty’ production technology with high per unit cost of emission reduction, although a cleaner one with lower per unit cost is available (Buchholz and Konrad 1994).⁴⁴

To sum up, instruments for the external stabilization of international environmental agreements are able to contribute substantially to their incentive compatibility. This holds for the incentives to sign international treaties on environmental policy as well as the willingness to comply with their obligations. Moreover, as the strategies discussed in this section are ‘external’ to the environmental content of an international treaty, they may in principle be applied to stabilize international cooperation in other policy fields as well. It must be emphasized, though, that in many cases even the combined recourse to all of the instruments that have been presented so far will not suffice to attain globally efficient cooperative solutions in international environmental policy. This is not only because the discussed strategies are second-best in comparison to the enforcement of treaties by a supranational authority, but rather because the maximization of joint welfare by coordinated environmental policies generally is not compatible with the pursuit of the individual interests of single countries. Given the diverging interests with respect to national pollution control, the governments of some countries may consider to take additional measures which go beyond what can be achieved by international negotiations. The effects of such unilateral and accompanying policy measures by single countries or

⁴⁴ Similar problems arise in the presence of asymmetric information between the donor and the recipient countries. Then, countries have an incentive to report on private information in a distorted manner. Thereby, recipient countries try to receive higher transfers, whereas donor countries try to free ride on the side payments of other donor countries.

subcoalitions on the incentives to participate in and comply with environmental agreements are discussed in the following section.

5 Unilateral measures

Instead of, or complementary to negotiating and cooperating with other countries on international environmental policy each government is free to undertake unilateral measures at any time. This may happen in the complete absence of any agreement, but also by taking up the role of a pioneer at different stages of the process of negotiating and implementing a treaty. Two questions arise in the context of unilateral policies to internalize transboundary environmental spillovers: (i) Which are the motivations of single countries to take up the role of a catalyst and promote international environmental cooperation? (ii) How can countries individually or jointly increase the effectiveness of their policies by accompanying measures that counteract negative adaptation processes from abroad?

The first question refers to motivations to engage in international environmental policy others than those presumed in the previous sections. For example, *social norms* may play an important role not only for the explanation of individual behavior, but also for the decisions of national governments in the diplomatic arena (cf. Hoel and Schneider 1997).⁴⁵ Governments may fear to be blamed as opportunistic and non-cooperative and therefore sign and stick to an environmental convention, even if in pure economic terms free-riding pays off. Formally speaking, taking into account such motivations amounts to expand the set of arguments in the utility (or welfare) functions of the players.

Especially in the political debate it is often proposed that particular countries should lead the way and undertake measures for the protection of international environmental resources independently from other countries. By „setting a good example“ they may initiate similar behavior of other countries because the latter would otherwise lose reputation for not being ‘cooperative’ or because they feel morally obliged to. The unilaterally acting countries may have an advantage in doing so if they can win recognition (‘moral leadership’) in the international arena. In addition, by implementing unilateral policies (e.g. through pilot projects

⁴⁵ For the role of social norms, intrinsic motivations and altruistic behavior see e.g. Elster (1989), Holländer (1990) or Sugden (1984).

or by promoting new and environmental friendly technologies) countries with a large concern for the environmental good in question may be able to provide valuable information, thereby facilitating negotiations. Of course, the provision of this information possesses itself a public good character and is subject to free rider incentives. Nevertheless, the marginal environmental benefit of one dollar invested in providing this information may be greater than from investing in domestic abatements.⁴⁶

Under traditional assumptions on the actors' preferences unilateral actions often are detrimental to the welfare position of the country undertaking these actions. Hoel (1991) for example shows the negative effects of unilateral abatements on a country's own bargaining position in the cooperative framework of a Nash bargaining solution. Individual countries suffer welfare losses if they unilaterally abate more before or during international environmental negotiations. In fact, from a purely national perspective governments will try to maximize their share of the total gains from international environmental cooperation by strengthening their position in the negotiations. The possible detrimental effects of pre-negotiation behavior on environmental protection is illustrated by Buchholz and Konrad (1994). In their model governments anticipate negotiations on the internalization of transboundary externalities. In order to strengthen their own bargaining position they choose an inefficient technology with high per unit costs of abatement before negotiations and cooperation start. The choice of technology is inefficient also from a national perspective, but works as a form of commitment for this country and therefore pays off. It is assumed that (abatement) technologies cannot be changed anymore once negotiations have started and that the outcome of negotiations is determined by the Nash bargaining solution. A country with relatively high marginal abatement costs then will have an advantage because it is globally efficient to assign a relatively small share of the abatement burden to this country.

Unilateral abatement measures of single countries may not only have adverse effects on national welfare by weakening the own bargaining position during negotiations, but they may even worsen *environmental quality*. This is shown by Hoel (1991) in a model where the cooperative equilibrium is determined by the Nash bargaining solution. The result, though, is

⁴⁶ A reason for unilateral environmental policy that is not motivated by environmental concern could be to obtain a competitive advantage in the development of new (and environmentally friendly) technologies. See Porter and van der Linde (1995) for this argument.

only valid for the scenario of elastic reaction functions and depends on the assumption that marginal abatement costs of the unilaterally acting country increase sufficiently stronger than those of the other countries. Moreover, the economic reason that makes a single country engage in unilateral abatements remains unclear. On the one hand, it is assumed that a unilaterally acting country is not on its 'true' best reply function. On the other hand, the true net benefits of abatements are relevant for the cooperative solution. If intrinsic motivations for unilateral measures are present in case of non-cooperation, these should also be considered for the cooperative solution; but if the exclusive motivation for unilateral action is to manipulate the outcome of negotiations, the true net benefits should be the basis of the decision-making. Finally, it is hard to justify why one does not assume the same behavior for (at least some of) the other players involved. Of course, in that case the result of a deterioration of environmental quality would hardly prevail.

A different approach is taken by Endres and Finus (1998) who analyze the effects of increased environmental awareness (i.e. a change in preferences) on the incentives for international environmental cooperation and environmental quality. In this framework unilateral measures are conform with optimizing behavior of national governments. In one part of their analysis the authors assume that the cooperative solution is characterized by uniform emission reduction quotas – the outcome of many real world negotiations on environmental agreements. They analyze the ecological effects of unilateral actions before negotiations start as well as of over-fulfilling the assumed environmental agreement after it has been signed. As in Hoel (1991) the result emerges that in many cases global emissions will *increase* due to unilateral environmental policy measures. However, the deterioration of environmental quality in this model is caused by strategically adjusted proposals and reduced abatements of countries that observe or anticipate unilateral measures by others. It is shown that the results depend on the stage at which the commitment of over-fulfillment is known to the parties involved and how they react to this knowledge. Both of the contributions cited above assume non-orthogonal reaction functions. Although this assumption is plausible from a theoretical point of view it remains open if it is also empirically justified. It implies that countries' abatement quantities are interdependent even in the non-cooperative equilibrium.⁴⁷

⁴⁷ For a critical discussion regarding this scenario see e.g. Carraro and Siniscalco (1993), p. 323–325.

The second question raised at the beginning of this section concerns the problem of how to protect individual or joint efforts to internalize transboundary externalities against detrimental reactions from abroad. This is relevant in our context of providing cooperation incentives because the more the environmental impact of a cooperative strategy is eroded by offsetting adjustment processes of non-cooperating countries, the less attractive it is to participate in an international environmental agreement. Such leakage effects may interfere with national abatement efforts via two channels: (i) directly, if marginal abatement benefits decrease in emission reductions and optimizing behavior leads to an adjustment of marginal abatement costs through higher emissions abroad; (ii) indirectly, due to a changed price vector general equilibrium effects lead to an international reallocation of polluting industries and change demand and supply of polluting goods abroad.⁴⁸ In the context of global warming the latter effect is well known as *carbon leakage*. Joint efforts of a subcoalition of countries to reduce their consumption of fossil fuels would tend to reduce world market fuel prices and thereby increase fuel consumption in non-signatory countries. In addition, an increased demand for imports of goods whose production is fuel-intensive would tend to increase fuel demand abroad even further.

One can think of different ways to counteract offsetting emission increases from countries abroad. An approach put forward by Bohm (1993) is to reduce the supply to non-signatories by having signatories buy or lease suitable fossil fuel deposits from producer countries. In case the unilaterally acting countries themselves are suppliers of fossil fuels, an alternative option is to influence supply by domestic policies as e.g. a tax on production and/or consumption of fossil fuels. As is shown by Hoel (1994) with a partial equilibrium model it is impossible to identify whether a demand or a supply policy is superior from the perspective of the subcoalition without additional information on the shape of demand and supply functions on the 'carbon market'. In general, some combination of positive production and consumption taxes will be better than one instrument alone.⁴⁹ However, to the extent that a single 'large' country or a group of cooperating countries exerts monopolistic power on the world carbon

⁴⁸ See e.g. Felder and Rutherford (1993); Merrifield (1988).

⁴⁹ See also Golombek et al. (1994) where the question is treated under which circumstances a tax per unit of carbon should be differentiated across *sectors* from the point of view of a subcoalition on climate protection.

market domestic policies do not only pursue environmental goals. They are also used to alter the terms of trade in a favorable manner. From the point of view of this optimal tariff argument the optimal policy mix will be to tax consumption and subsidize production or vice versa, depending on whether the coalition is in equilibrium a net importer or exporter of carbon. Hence, the optimal intervention on supply and demand of fossil fuels from the perspective of the unilateral actor depends on the relative importance of the damages from climate change and the gains from manipulating terms of trade.⁵⁰ A third strategy would be to induce cooperation of other countries to influence the demand and/or supply abroad. This requires instruments having been already discussed in the previous sections, especially the compensation of non-cooperating countries for the free-rider gains they forego due to cooperation (cf. Bohm 1993, Hoel 1994).

It remains to note that in contrast to the legal meaning of the term ‘unilateral’, it makes principally no difference if such measures are taken by one single country or if they are the outcome of a coordination between a subgroup of countries. With respect to the external effects of its coordinated measures a subcoalition faces the same patterns as an individual country. Therefore no strict separation can be made between cooperative and unilateral internalization strategies and in so far the above considerations apply for subcoalitions as well.

6 Flexibility and framework provisions

The last category of instruments to support incentives for stable international environmental cooperation consists of measures that are effective mainly in the long run. These are provisions which increase the flexibility of an agreement with regard to adaptations to new and previously unknown circumstances; they may also aim at ameliorating the general framework of international negotiations and treaties. In the moment of negotiating and signing an environmental treaty it will be impossible in many cases to foresee the development of all relevant factors, especially if the agreement reaches far into the future. If at some point in the future important parameters as e.g. per capita income, technology or the natural situation

⁵⁰ Similar results are obtained by Killinger (1996) in a general equilibrium framework with two countries where one ‘large’ country uses its market power for an *indirect internalization* of transboundary externalities from abroad.

change in a substantial and not foreseeable way compliance with an existing agreement may no longer be optimal for some countries. In order not to endanger the whole cooperation provisions may be included into the treaty which allow for a flexible adjustment of its terms in future periods without undermining the substance of the cooperative solution. Examples for such flexibility clauses include indexing national obligations to central economic variables as national (per capita) income or population size and conceding *escape clauses* for special circumstances (cf. Heister et al. 1995). More far-reaching adjustments could be arranged by renegotiating the treaty. This, however, has a de-stabilizing effect and therefore can be counterproductive if renegotiation does not take place due to unforeseen changes, but in reality is triggered by defecting behavior in the past. Hence, there might be a trade-off between the flexibility and effectiveness of an international environmental agreement (cf. Kerr 1995).

In the longer run, incentives for international environmental cooperation can be affected also generally in a rather fundamental way. One crucial factor for the success of negotiations is the information available to the governments involved. This is especially true for a coordinated internalization of global environmental externalities in view of the substantial uncertainties over physical and biological regularities and their economic consequences. In this context an important instrument for facilitating environmental cooperation consists in improving the relevant information for negotiations and making it accessible to all parties. This is a traditional task of international organizations and research facilities. Another long-run strategy is to pursue a general policy of global integration in order to increase the political and economic interdependencies between national jurisdictions. The latter makes it generally more difficult for a single country to behave in an opportunistic manner. The literature on issue linkage suggests that generally the more paths are open to punish non-cooperative behavior, the higher the degree of integration is.

7 Conclusions and outlook

The purpose of this paper was to survey recent contributions to the rapidly growing theoretical literature on international environmental cooperation. We proposed a taxonomy of instruments to create incentives for the participation in and compliance with international environmental agreements. The conceivable strategies to promote a successful coordination of environmental policies have been grouped into (i) the choice and detailed form of the internalization

instrument itself; (ii) carrot-stick strategies that make cooperative abatement efforts dependent on the past behavior of other countries (internal stabilization); (iii) transfers and sanctions of various forms (external stabilization); (iv) unilateral and accompanying measures by single countries or subcoalitions; and (v) long-term provisions to increase the flexibility of agreements and to improve the framework conditions of international negotiations.

The existing economic models on international environmental cooperation leave an ambivalent impression. On the one hand, this body of literature has overcome and to some extent replaced the traditional theory of environmental policy by taking into account the aspect of incentive compatibility and by shifting the focus from pure efficiency aspects to the distributional implications of international environmental policy. In this view the central merit of the contributions surveyed is that they address the fundamental institutional restrictions which apply to international environmental problems. These restrictions give rise to the second-best character of international environmental policy and the common feature of numerous models that international environmental cooperation will be only partial. Although the contributions have shown that in theory there is quite a variety of instruments available to provide incentives for stable environmental cooperation, in practice the requirements (e.g. on inter-temporal discount rates) for these strategies to be successful are often not fulfilled. Nevertheless, in comparison to no cooperation at all substantial mutual welfare gains can be realized if the discussed instruments are appropriately used.

On the other hand, the limitations of this body of literature cannot be overlooked. Due to the application of game theory for the analysis of national governments' strategic decisions on international environmental policy the assumptions on the rationality of the 'players' are often quite strong. The framework in which these decisions are taken often does not sufficiently take into account crucial aspects of real-world decisions on environmental policy, as for example substantial uncertainties and situations of incomplete information. Furthermore, the central paradigm underlying all of the contributions discussed is that of *rational opportunism* of national governments which act on behalf of their sovereigns. Outside the realm of economic, especially (traditional) game-theoretic theory, this rather narrowly defined notion of rationality is challenged as an appropriate assumption to analyze the incentives for cooperation between sovereign states. From the point of view of regime theory (a branch of political science analyzing international relations), negotiating an agreement is part of the formation of a regime where countries "*alter their behavior, their relationships, and their expectations of one*

another over time in accordance with its terms" (Chayes and Chayes 1993, p. 176). This perspective emphasizes the communicative and informing character of the whole process of international negotiations which modifies itself the structure of the decision problem, but is treated as exogenous in the traditional economic analysis (see e.g. Young 1989).

Most importantly, the central assumption underlying almost all of the models on international environmental cooperation is that governments are taken to act in a benevolent manner on behalf of their national population, the latter being treated as an homogeneous entity (the so-called *unit actor* assumption). Contributions that analyze environmental decision-making from a political-economic perspective have been made only recently and are very often restricted to non-transboundary externalities. It seems to be the most promising direction of future research in this field to mend this shortcoming and to develop models that are more concerned with a *positive* analysis of international environmental agreements. To this end economic models may also draw inspiration from already existing approaches in the political science literature like for example the analysis of „two-level-games“.

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