Incentives for International Environmental Co-operation - The Flexible Mechanisms of the Kyoto Protocol

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Preface

This thesis has developed over several years. My starting point was that I wanted to learn more about international environmental issues. Before I ended up with climate change and the flexible mechanisms of the Kyoto Protocol I studied both literature on trade and the environment and conservation of biological diversity. Although I don’t use much of what I have learnt about these two latter themes in this thesis, I believe it was not all in vain. It can some times be hard to remember that exams or a thesis are *not* the aims of studying. I am glad I have let my interests lead me on, even if it is a long and winding road.

I thank my supervisors, Carl-Erik Schulz and Derek Clark, which even though they must have had their doubts if I ever would finish, always have been supportive. I must also thank Carl-Erik for letting me be a research assistant on his trade and environment project in 1994.

I thank my fellow students at the Department of Economics for providing an environment that was positive, giving much distraction from my studies.

I must especially thank Ina and our two boys Birk and Brage, the Department of Environmental Affairs at the Office of the Finnmark County Governor, and everything else that has helped delay this thesis, while at the same time making my life richer and more meaningful.

Life *is* what's happening to you, while you’re busy making other plans…

Eirik Inge Mikkelsen
Tromsø, August 2000

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Summary

In this thesis I have taken a broad view on international environmental co-operation; What are the incentives, obstacles and ways to enhance participation and compliance with international environmental agreements. I have also looked at a more specific issue; The implementation of the "flexible mechanisms" of the Kyoto Protocol, and particularly joint implementation projects between an investor in a developed country and a host in an economy in transition or developing country.

Full co-operation in dealing with international environmental externalities will give the highest sum benefit for the countries involved, but countries have the incentive to increase their individual benefit by free-riding on the virtuous behaviour of others. As there is no supra-national authority to enforce compliance, this can make co-operation break down or keep it from being established.

To enhance co-operation it must be made beneficial for each individual country to join an IEA, and free-riding and non-compliance should be deterred. Several mechanisms can promote co-operation, like side-transfers, issue-linking and trade-sanctions. Several authors also see countries' moral obligations and commitment as possible important factors in this.

Contrary to basic economics theory, compliance with international environmental agreements (IEAs) is the norm. Several explanations to this are possible. An IEA may be seen as the outcome of a non co-operative game, and hence only reflects each country's costs and benefits of that underlying game. Countries are free to negotiate and join the IEAs they choose, perhaps opting out of costly "deep co-operation".

To have mechanisms for efficient implementation of an IEA will make it easier for countries to join and comply. However, achieving overall efficiency seem unlikely. It requires both that targets are set optimally and the agreed measures must be implemented cost-efficiently. Mechanisms to achieve cost-efficiency exist, but have their problems.

The Kyoto Protocol opens up for such flexible mechanisms: International emissions trading (IET) and joint implementation (JI). To minimise costs of implementation measures to combat global warming must be performed also in economies in transition and developing countries, but the developing

countries do not have obligations under the protocol. For JI-projects between an investor in a country with obligations and a host in a country without obligations the Kyoto Protocol includes the Clean Development Mechanism (CDM). The detailed rules for all these flexible mechanisms have not yet been agreed upon.

For IET possible problems with countries' market power in the emissions quota market, limited participation in trading, high transaction costs, asymmetric information opening up for cheating and the trade of "hot air" can reduce the cost-saving, or even lead to higher overall costs of implementation.

For JI (includes the CDM) one fears that high transaction costs, asymmetric information opening up for adverse selection of projects and hidden action by the hosts, "paper trades" due to missing emission baselines for the developing countries, limited participation and leakages will limit their cost-saving ability.

I believe JI-project investors will try to perform several projects with the same host to reduce transaction costs of each project. Due to financial constraints hosts in developing countries and economies in transition will need to get all or some of the project transfer before performing the project. I have developed two models in this thesis to investigate if JI-contracts are possible under these assumptions. I find that even if external uncertain factors can cause project failure and the host has private information opening up for cheating, contracts can be possible. To increase the chances of JI-projects the external factors' influence should be reduced. A JI-project host should work to reduce a host's private information, to avoid own benefit of the project being eliminated due to contract breach by the host.

Contents

1. INTRODUCTION

Public interest for environmental issues became widespread in the 1960s in the advanced economies (Baumol and Oates 1988). Local pollution problems (Pigou 1920, Carson 1960) and national losses of wildlife (Zappfe 1958, Leopold 1966) were the first environmental concerns. Today international issues like acid rain, climate change, thinning of the ozone layer and global losses of biological diversity dominate, at least in the Western Hemisphere.

For local/domestic environmental externalities the basic theory on how to resolve them has existed for more than 3/4 of a century. The authorities must correct the externalities through the use of taxes and/or direct regulations (Pigou 1920). Which instrument is most efficient varies with the amount of information available to the authorities and whether uncertainty is present. An important addition to the theory on externalities came with Dales' theory on tradable permits in 1968.

The instruments prescribed for domestic environmental externalities can not be used as easily for international problems. States are sovereign, and the lack of a supranational authority is the biggest obstacle to an efficient elimination of international externalities (Barrett 1990). All the involved states must co-operate to resolve an international externality if efficiency shall be achieved. At the same time as this highest benefit is an incentive for international environmental co-operation, countries also have an incentive to free-ride on the virtuous behaviour of others. Barrett (1994) states that international environmental agreements (IEAs) must be self-enforcing, meaning that they must be designed so that it is in countries' interest both to join and comply with them.

International environmental problems are the concern of this thesis. International environmental agreements (IEAs) are between states, and aim to prevent, reduce, control or compensate for transboundary environmental externalities (Måreng 1996). The agreements can be bilateral, trilateral or multilateral, including agreements for the global commons.

Since 1869 more than 300 IEAs have been signed, with approximately 200 of them since 1970 (Måreng 1996). There are several types and levels of IEAs which countries may negotiate (Ulfstein, lecture 14.05.98):

- In *declarations* states together pronounce their good intentions for future behaviour or co-operation;

- *Framework conventions* state the aim of a co-operation, but not the concrete duties that the signatories must perform;
- By signing *Protocols* (under conventions) states accept concrete duties, like reductions of emissions by a certain percentage compared to a benchmark;
- *Lists* may give details of substances which the states may not produce or consume, of species which may not be traded, etc;
- States may agree to create international institutions working for international co-operation on the environment.

Of all IEAs set up since 1972, 2/3 deal with shared resources. The IEAs made up to the end of the 1970's are called first generation agreements. They were technical agreements, with no or only weak built in mechanisms for resolving disputes/dealing with non-compliance. Their goal was often to agree on a flat rate reduction on polluting emissions. Second generation agreements, up to the end of the 1980's, have provisions on just sharing of the burden, provisions to achieve cost-effectiveness, and prescribe measures based on scientific investigations. During the last years we have got third generation agreements. In addition to the good features of 2nd generation IEAs, they contain explicit provisions on compliance, verification and enforcement of the agreement. (Måreng 1996).

A functioning IEA has four elements according to Måreng (1996): Implementation, compliance, verification and enforcement. Implementation is the measures taken at the national level to realise the obligations of the agreement. This could for example be altering or making new national laws. Compliance is when the implementative measures are respected/performed by the nation's citizens, enterprises, etc, and the state hence fulfils its obligations under the IEA. Verification is the collection and evaluation of information about how the states fulfil their obligations in the IEA. Enforcement of an agreement is necessary when states do not fulfil their obligations, and can take the shape of "carrots" or "sticks". It could also be putting dispute-resolving mechanisms into effect between two or more parties disagreeing about their fulfilment of the IEA.

Carraro (1997a) notes that in the recent history of IEAs, conventions signed by many are rather empty in terms of quantitative targets and/or deadlines. Precise commitments are on the other hand signed by a small group of "like-minded" countries.

Many different solutions have been proposed and some implemented. For global environmental problems, like the decline in biological diversity, one must, through international institutions, create mechanisms that will register the preferences and concerns of the global community with the local communities from which the externality stems (Swanson1994). Side-transfers are used in some IEAs as an instrument to increase the number of signatories (Carraro and Siniscalco 1993). Coercive trade measures are potential "sticks" in a few current international agreements to deter free-riding (Blackhurst and Subramanian 1992). "Carrots", like technical assistance and financial transfers, are however a lot more common (Jacob Werksman, lecture 15.05.98). Current negotiations are trying to link environmental protection to other types of international co-operation. An example is the technological co-operation under the Climate Change Convention. (Carraro 1997a).

That the implementation of a country's obligations under an IEA is cost-effective is often the responsibility of that country. In some cases the design of the IEA can influence the overall cost of meeting its target considerably. The Kyoto Protocol under the Framework Convention on Climate Change opens up for several mechanisms that can equalise marginal costs internationally. By allowing *international emissions trading* (IET) countries can buy emissions quotas abroad. The seller of the quota has a lower marginal cost of reducing emissions than the buyer, and both can make a gain. In *joint implementation* (JI) projects countries (or sectors/firms) makes investments abroad that reduce emissions, and the investor can get this credited towards their own obligations. It is a requirement that the reductions from the JI-project are additional to what would have taken place in the absence of the project. If the host country also has a target under the Kyoto Protocol this is unproblematic. However, the majority of the world's countries – the developing countries – have no obligations to reduce emissions of greenhouse gases under the Kyoto Protocol. The *Clean Development Mechanism* (CDM) is a mechanism that allows JI-projects between investors in countries with obligations and hosts in countries without obligations, provided the investments also aids development of the host country.

In chapter 2 I discuss the incentives and mechanisms that naturally exists for countries to make and fulfil IEAs, and in chapter 3 how the design of IEAs can make it more attractive to join them, and what types of mechanisms can ensure or increase compliance with the demands of an IEA. These two chapters constitute a background for the discussion on mechanisms and measures to get an efficient implementation of countries' obligations under an IEA (chapter 4). Focus is on the flexible mechanisms in the Kyoto Protocol:

- International emissions trading (IET);
- Joint Implementation (JI) (including);
- the Clean Development Mechanism (CDM).

The cost-efficiency potential that these mechanisms hold may not be achieved due to problems with transaction costs, enforcement, asymmetric information and uncertainty. The detailed rules to govern the use of these mechanisms are not yet decided. They might be agreed at the sixth Conference of the Parties (COP-6) to the Framework Convention on Climate Change (FCCC) in the Hague, in November this year (2000).

In chapter 5 I develop two models that investigate repeated international contracts under asymmetric information and uncertainty. I argue that the models' assumptions are relevant for some JI-contracts. In particular:

- To reduce the transaction costs of each individual JI-project the investors will probably limit their co-operation to only a few hosts, learn to know them well, and rather perform several JI-projects with each. Hence I model a repeated relationship between investor and host of JI-projects.
- The countries where the cheapest measures to combat global warming are (lowest marginal cost) are developing countries and the Economies in transition (former Soviet Union/Eastern Europe). Generalising, one can say that these countries are politically and economically unstable, with much corruption present. These factors might cause project failure independent of a host's actions. The presence of uncertainty increases the chances of hosts to JI-projects trying to cheat in some manner, especially if a host has private information.
- Some hosts of JI-projects will need to receive the contracted transfer before the project is implemented, due to financial constraints. Withholding the transfer to achieve compliance is hence not an option for the investor.

These starting point are common for both models. The second model investigates how a host's ability to reduce other factors' influence on the outcome of a JI-project affects the chances of JI-contracts and the actors' strategies.

In chapter 6 I sum up and conclude.

2. NATURAL INCENTIVES FOR INTERNATIONAL CO-OPERATION

When international environmental externalities are present there is a potential gain in co-ordinating actions (Barrett 1990). This is the basic incentive behind making IEAs. It is common in situations with international externalities that no country can gain by unilateral action. The Prisoners' Dilemma is the standard representation of (reciprocal) externalities (Blackhurst and Subramanian 1992), and this was also the game used in early analysis of international environmental problems (Carraro and Siniscalco 1992). It demonstrates the disincentive for unilateral action, but also the incentive to free-ride if others try to deal with the externality. No co-operation is the predicted outcome. The incentives for co-operation can be stronger if the situations are repeated (repeated games), if the countries are highly heterogeneous, or if there is "*reciprocity*" between the players (Blackhurst and Subramanian 1992). If there are reinforcement effects between the environmental efforts of the different countries (Heal 1994), and the more farsighted the countries are (Ecchia and Mariotti 1997), the chances of reaching a co-operative solution is also higher.

There is a need for mechanisms/institutions that can make it profitable for individual states to take their external effects on other countries into consideration when making decisions (Swanson 1994). IEAs are set up to achieve co-operation and to punish free-riding (Barrett 1994). As no sovereign country can be forced to join an IEA, nor comply with its obligations, an agreement must be "self-enforcing"; Each individual country must be better off by joining and complying with an IEA (Barrett 1994).

2.1 The potential gains of international co-operation

If countries co-operate to maximise their joint total benefit, there is a gain compared to the situation where each country only maximises individual benefit, ignoring the external effects they impose on the others. That gain is the potential gain of international co-operation (Barrett 1990).

In many cases the gain is similar to the gain of having efficient provision of a public good, compared to private provision of it. This is because some internationally shared resources have public good characteristics (Barrett 1994). This is also reflected by the rule used in setting the level of abatement when co-operating on pollution control; It is just a restatement of Samuelson's rule for the optimal provision of a public good[1].

To illustrate the point Barrett (1990) considers a world of N identical countries, each of which emits a pollutant that damages the global environment. Every country's marginal benefit of abatement depends upon global/total abatement level[2], while its costs naturally only depends on its own abatement level. Linear marginal benefits and costs, are assumed.

See Figure 1 below. The non co-operative (Cournot-Nash) outcome of the situation is that each country chooses a level of abatement where its own marginal benefits (MB_i) equals its own marginal costs (MC_i). This is level Q_0. With a fully co-operative outcome each country abates to the level where its own marginal costs equals the sum of marginal benefits of all the countries taken together (MB). This is the higher abatement level Q_C.

[1] Samuelson, P 1954:"The pure theory of public expenditure", *Review of Economics and statistics*, 36, 387-9, quoted in Barrett (1994).

[2] The benefit of abatement is alternatively viewed as the reduction in damages due to a lower pollution level.

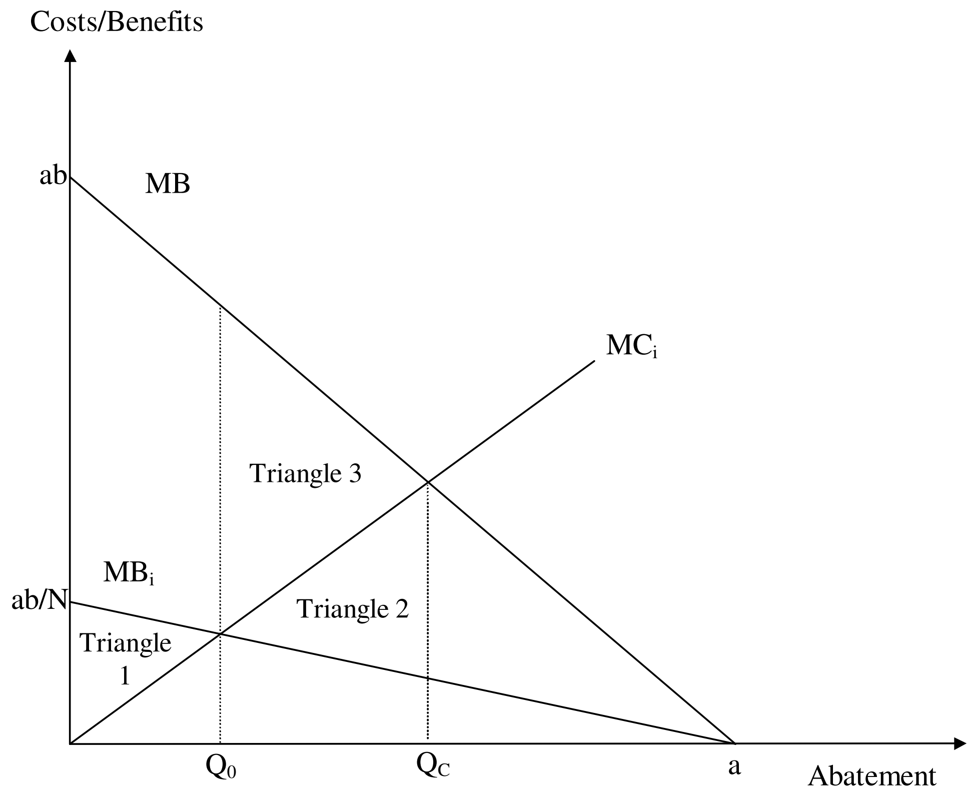

Figure 1 - The potential gains of co-operation

In the non co-operative case, each country has a net benefit given by the area of triangle 1. Moving to the co-operative case the area of triangle 2 represents the country's increased cost by doing so. This is more than offset by the increase in the other countries' benefit, and the total net increase in benefit is given by the area of triangle 3.

The difference in abatement levels between the co-operative and the Nash outcome depends on the slopes of the individual country's marginal cost curve and the slope of the global marginal benefit curve, and also the total number of countries (Barrett 1994). Barrett (1994) finds that for global environmental problems, with the number of countries being large:

- When cost of abatement is small and benefit is large, abatement is substantial even in the Nash outcome. The gains to co-operation is hence relatively small in this case.
- When cost of abatement is large and benefit is small countries will not abate much, even with full co-operation.
- When cost of abatement is approximately equal to the benefit and both are relatively small, full co-operation will mean substantially higher abatement levels than in the Nash outcome, but the gains of co-operation will nevertheless be small.
- When cost of abatement is approximately equal to the benefit and both are relatively large, full co-operation will mean relatively high abatement levels and large gains of co-operation.

In the real world countries are not identical. Some countries will then gain and some lose when moving from the non-co-operative to the co-operative outcome. This depends on the relative size between the benefits of increased overall abatement and the costs of own abatement (Hoel 1992)[3].

2.2 Obstacles to co-operation

Blackhurst and Subramanian (1992) give four reasons why countries may not want to participate in an international environmental agreement:

- Disagreement over scientific evidence. Some countries may consider the problem exaggerated or non-existing, or that the proposed remedies will be ineffective. There will always be *uncertainty*, and it is a underlying cause for many types of problems related to international co-operation.
- A country may give lower priority to a particular environmental problem than the proposers of the IEA. This could take the form of a dispute over the relative size of costs and benefits. Differences in concern for an environmental issue typically stems from differences in preferences, per capita income, environmental endowments or expectations of future technological innovations.
- A country may disagree with the proposed sharing of responsibility between countries for the environmental problem. The allocation of responsibility is linked to the question of property rights. At a national level a major distinction is between the polluter pays principle and victim pays principle. At a multilateral level this distinction is more complex. Coase (1960) states that, if property rights are allocated between parties experiencing externalities, there will be no need for intervention by the authorities. Negotiations between the parties, on their own initiative, will ensure an economically effective solution, providing these negotiations are not too costly. For international externalities the negotiations to agree on property rights may themselves be so complex that the associated costs bar an agreement.
- A country may be trying to free-ride on the efforts of other countries to solve a problem associated with international externalities[4]. A situation with private information (*asymmetric information*) may increase the chances of countries cheating.

Potentially high transaction costs can also be a factor that keep countries from involving themselves in negotiations (Coase 1960).

[3] Hoel 1992: “International environment conventions: ‘The case of uniform reductions of emissions”, *Environmental and Resource Economics,* 2, 141-160, quoted in Petrakis and Xepapadeas (1996).

[4] Characterisation of free-riding is also a statement about property rights. What some could call free-riding, others could say was legitimate exercise of a right (Blackhurst and Subramanian 1992).

2.3 Game representation of international co-operation

The game of the Prisoners' Dilemma is the standard representation of externalities, including public goods, where actors in the pursuit of private gains impose costs on each other, (Blackhurst and Subramanian 1992). A version of the 2-player Prisoners' Dilemma for the case of abatement-efforts to deal with the pollution of a common resource is given below (from Blackhurst and Subramanian 1992). Co-operation means choosing a higher level of abatement than with non-co-operation, just like in Barrett's model above (Barrett 1990), and the reduction in damages outweighs the increase in abatement-costs if all countries co-operate.

		Country B	
		Co-operate	Not co-operate
Country A	Co-operate	(3,3)	(1,4)
	Not co-operate	(4,1)	(2,2)

Table 1 - The Prisoners' Dilemma of bilateral co-operation[5]

With a one-shot Prisoners' Dilemma, with no authority to enforce co-operation, the countries are stuck with the (2,2) payoff of non co-operation. If one country considered unilateral action, meaning a higher level of abatement than in the Nash outcome (where own marginal abatement costs equals the marginal reduction in pollution damages), it would experience a net loss. It is clear that the countries would be better off by co-operating (with the payoff of 3), but also that if they had an agreement to co-operate both would have a constant incentive to defect, hoping for the higher payoff of 4. The strategy of not co-operating is dominant for both countries, meaning that the order of play and the information sets are irrelevant for the outcome of the game (Rasmusen 1989).

Barrett (1999) models a N-player prisoners' dilemma, representing the game of international co-operation to provide an international public good[6]. The players again choose between co-operation (C) or non-co-operation (=defection; D). The payoffs are increasing in the number of players that play co-operate, z ($0 \le z \le N$):

$$\Pi_D(z) = bz$$

Equation 1

and

$$\Pi_C(z) = -c + dz$$

Equation 2

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[5] The first number in each pair is A's payoff.

[6] Climate change and destruction of the ozone layer are good examples of this (Barrett 1999).

In these equations b, c and d are parameters, and the payoffs are normalised so that $\Pi_D(0) = 0$. The parameters must be adjusted to fulfil the 3 requirements of the prisoners' dilemma:

1. In the one-shot game it is a dominant strategy not to co-operate.
2. A country's payoff is increasing in the number of countries that co-operate, independently of whether that country co-operates or not.
3. The Nash-equilibrium of the one-shot game is inefficient, and all countries would prefer a outcome where at least some countries co-operate.

For the first requirement, Barrett (1999) finds:

$$bz > -c + d(z+1) \quad \text{for all } z;\ 0 \leq z \leq N-1$$

Equation 3

For the second:

$$b > 0\ , \quad d > 0 \quad \text{and} \quad c > d$$

Equation 4

If one assumes that the aggregate payoffs are strictly increasing in the number of co-operating countries (z), the third requirement gives:

$$-c + 2dz > b(2z - N) \quad \text{for all } z;\ 0 \leq z \leq N-1$$

Equation 5

The internal relationship between b and d can be $d > b$ or $d = b$. This depends i.a. on whether co-operation has increasing returns. Barrett (1999) allows for both and assumes

$$d \geq b$$

Equation 6

Hence

$$c > d \geq b > 0$$

Equation 7

In the one-shot game, everybody will defect. All countries prefer full co-operation to this outcome. Full co-operation gives the highest aggregate welfare. Barrett (1999) defines the problem of international co-operation (in this context) as how to sustain the full co-operative outcome as an equilibrium of a repeated game with strategies of reciprocity.

If the prisoners' dilemma is played repeatedly it is possible to sustain co-operation with several types of strategies (Barrett 1999).

- Grim strategy: All agree to co-operate the first period, and as long as no-one has defected. If someone defects, everybody plays defect forever after.
- Tit-for-tat: The players play the strategy this period that the others played last period.
- Getting-Even: A player co-operates this period unless it has defected less often than any of the other players in the past.

Grim is both individually rational and sub-game perfect. Individually rational means that no player can do any better on his own than to play the strategy, given that everybody else also play that strategy. But Grim is grossly unforgiving, and "the punishment does not fit the crime". Countries also have incentive to *collectively* deviate from the strategy. Grim is not a collectively rational strategy. (Barrett 1999).

With Tit-for-tat the punishment better fits the crime. But if the first player to deviate returns to co-operation and Tit-for-tat the next period, and the others stay with it, we will have an unending echo of alternating defections. Hence the players could do better by deviating from the strategy after the one-off deviation. Tit-for-tat is not sub-game perfect, and it is not an individually rational strategy. (Barrett 1999).

Getting-Even in a 2-player game mean that if one player deviates for 20 periods and then reverts to co-operation, the other player will not revert to co-operation for another 20 periods. This strategy can be both individually and collectively rational, Barrett (1999) demonstrates. Getting-Even will be collectively rational if the players have no incentive to renegotiate the agreement after one country has deviated. By comparing each country's payoffs in the punishment-phase of Getting-Even (=b), with their payoffs if they all deviate (= -c + dN), Barrett (1999) finds that it will be a collectively rational strategy provided:

$$\frac{b+c}{d} \geq N$$

Equation 8

Agreements that satisfy this requirement are renegotiation proof, and the threats to sustain full co-operation are credible. This means Getting-Even can sustain a *self-enforcing agreement* when Equation 8 holds. More on self-enforcing agreements in the next chapter.

The chances of co-operation are, in addition to repetition, changed with (Blackhurst and Subramanian 1992):

- Non-identical players;
- Allowing for reciprocity, including issue-linking.

As the number of potential members in an IEA grows, the free-rider problem becomes bigger. Both the individual country's need to participate and the incentive for punishing individual free-riders becomes smaller (Blackhurst and Subramanian 1992).

However, the number of countries needed to reach an acceptable solution can be reduced as the differences between countries likely also become bigger with higher numbers. In a very asymmetric situation a few key players can solve most of the problem through co-operation, tolerating free-riding from non-key countries. The Kyoto-agreement is to a degree an example of this, with developing countries having no obligations (at this stage?) and the industrialised countries paying the full cost (Jacob Werksman, lecture 15.05.98).

Blackhurst and Subramanian (1992) refer to two different types of *reciprocity*, from the work of Keohane[7], that may help the situation. Reciprocity refers there to the exchanges of roughly equivalent values in which the actions of each party are contingent on the prior actions of other parties, such that good are returned for good, and bad for bad.

Specific reciprocity is when partners exchange items of equivalent value. This can be a useful concept and strategy in situations with few actors and private goods. For cases with large numbers of countries, public goods, and hence probably free-riders, it is less useful. This is due to free-riders' access to the public good regardless of their and others' efforts, and also that individual countries have little incentive to police an agreement. (Blackhurst and Subramanian 1992)

Diffuse reciprocity is a broader concept, relating to a sense of obligation between players; "If others are contributing so should I". With this approach free-riding can be overcome even in one-shot games (Blackhurst and Subramanian 1992). In families and in small communities diffuse reciprocity is common. With relationships on a larger scale it gets more difficult, but not impossible. In debates in the House of Commons in Great Britain it have been urged, on the grounds of fairness, that Great Britain should contribute to the resolution of international environmental problems, provided others do the same (Barrett 1990). Barrett (1990) refers to this as "morality" in international relations. Hoel (1994) believes that social norms and conventions may play an important role in sustaining agreements between governments.

The emergence of an international society with many overlapping interest and concerns also strengthens this view of diffuse reciprocity (Carraro and Siniscalco 1998). Co-operation in a multitude of areas are linked in an informal and complex way, and what was earlier considered as an individual "Prisoners' Dilemma" now becomes embedded in a broader social context; Countries fear that lack of co-operation in one area may spread to others, they prefer to co-operate, and hence add to the sense of diffuse reciprocity between countries (Snidal 1985[8]). Formal issue-linking in IEAs is investigated in section 3.3.

Heal (1994) shows that if there are "*reinforcement effects*" between the environmental efforts of countries, individual countries' optimal effort may be shifted from zero to a positive level. Reinforcement effects are present when a country's benefit, for example of own abatement levels,

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[7] Keohane 1986: "Reciprocity in international relations", *International Organisation,* 40: 1-27.

[8] Snidal 1985: "Co-ordination versus Prisoners' Dilemma: Implications for international co-operation and regimes", *The American Political Science Review*, 79:923-42, quoted in Blackhurst and Subramanian (1992).

rises with increasing abatement levels of other countries, or the costs of own abatement is reduced with increasing abatement efforts of other countries.

With net benefits by country *i* being given by

$$B_i(X_1,X_2,..X_i,..X_n)-C_i(X_1,X_2,..X_i,..X_n)$$

where
B_i is *i's* benefit of the environmental efforts (e.g. abatement) X_j of all *n* countries,
C_i is *i's* cost of own environmental effort, also depending upon the X_j of all *n* countries,

reinforcement effects are present when

$$\frac{\partial^2 B_i(X_1,X_2,..X_i,..X_n)}{\partial X_i X_j} > 0$$

Equation 9

and/or

$$\frac{\partial^2 C_i(X_1,X_2,..X_i,..X_n)}{\partial X_i X_j} < 0 \, .$$

Equation 10

If environmental efforts are complementary across countries, the levels of effort in the Nash equilibrium will be positive. Heal (1994) claims that such a coalition, where every member's level of effort is positive (when they maximise net benefits), *given* the choices of others, *is immune to the problems of free-riding*, and the Prisoners' Dilemma paradigm is not applicable. Intuitively it seems wrong that positive complementarity will necessarily *eliminate* the problems of free-riding, but it will alleviate them.

Ecchia and Mariotti (1997) consider how *farsightedness* can affect international co-operation. They distinguish between two main cases of international environmental problems. One fits the Prisoners' Dilemma described above, the other has the features of the Chicken game. In the Chicken game the consequences of no co-operation at all will be an environmental disaster, and individual countries would prefer unilateral action from that outcome. In the Prisoners' Dilemma it is always a dominant strategy for a myopic country to pollute, and the incentives to free-ride are the strongest in this game. From the collective point of view an agreement is however better than no co-operation. In the Chicken game there are also incentives to free-ride on the efforts of others, but there is also an incentive to unilaterally leave the position which is the most damaging for the environment.

Ecchia and Mariotti (1997) assume that the countries consider different outcomes, and then have the possibility to change their position, or to propose to other countries to make up a (temporary) coalition which will jointly deviate from the present position. Countries negotiate until they end up at a position which no single country, and no coalition of countries, wants to deviate from. Then, and only then, are the payoffs given to the countries. Their idea of strategic farsightedness is captured by payoffs being distributed only when countries have agreed on a permanent position.

Ecchia and Mariotti (1997) considers a model with 3 countries. They consider for each type of game 2 sub-versions. In the *Strong Prisoners' Dilemma* the strategy of one country has been fixed, and in the 2-player subgame the co-operative outcome is Pareto-dominated by the fully non co-operative outcome[9]. In the *Weak Prisoners' Dilemma* the co-operative outcome of the 2-player subgame Pareto-dominates the fully non co-operative one.

In the Strong *Chicken* game each of the 3 countries only have an incentive to free-ride when both other countries co-operate. In the weak version a country will free-ride if one of the other countries have the co-operative level of environmental efforts. In the Strong Chicken game the environmental disaster will occur even if only one single country free-rides. In the weak version two countries must play the non co-operative level of environmental effort for the disaster to occur.

A conclusion of Ecchia and Mariotti (1997) is that farsightedness can lead to a high degree of international co-operation. Full co-operation is always a possible outcome, and in no case is there a majority of free-riders. This can be contrasted to the findings of for example Barrett (1994) and Carraro and Siniscalco (1993) in the next section.

2.4 Self-enforcing agreements

In international law there is no authority to define what is right and what is wrong. It is also impossible to enforce obligations states undertake by signing international agreements unless one resorts to military or economical coercion (Ulfstein, lecture 15.05.98).

This means international environmental agreements (like other international agreements) must be profitable to join and to fulfil the obligations of, *for individual countries* (Barrett 1994). Such IEAs are called *self-enforcing*. The self-enforcing IEA should ideally result in the fully co-operative outcome, maximising the sum net benefit of all countries.

That it is profitable to sign an IEA is a necessary but not sufficient condition for it to be self-enforcing. Free-riding must also be avoided. The coalition of signatories must hence be stable (Carraro 1997a).

[9] The basic feature of the Prisoners' Dilemma is most clearly present in the strong version, hence the terminology.

Barrett (1990) was the first to use the term self-enforcement, at least in this context. The benefit of participating in an agreement, or alternatively free-riding on it, depend on the number of signatories to the agreement, and the commitments they make. Commonly, when the number of co-operating countries grows above a certain limit, the benefits of free-riding becomes larger than the benefits of joining the agreement. Then no more countries will join. That limit defines the maximum size of a self-sustained, stable coalition, and hence the self-enforcing agreement (Barrett 1990).

Heal (1994) introduces a concept related to Barrett's concept of self-enforced coalitions. Heal states that a *critical coalition* is a coalition of countries where each individual country have larger benefits than costs from the environmental effort. A *minimum critical coalition* is a critical coalition where no subset of the coalition is also a critical coalition. Heal (1994) considers critical coalitions both with and without side-payments between their members.

Barrett (1994) models a situation with transboundary pollution, where the signatories to an agreement optimise their joint emissions-strategy. The signatories accept that others will free-ride, and optimise their joint emissions taking this into account. The non-signatories play Nash, maximising their own individual benefit. The model is used to investigate the relationship between the total number of countries and the size of the self-enforced coalition, and the difference in net benefits between full co-operation, the self-enforced agreement and the Nash outcome. All countries are assumed identical.

As the number of signatories increases the abatement effort of each signatory goes up, rewarding the newcomer, but also making free-riding even more profitable. When Barrett looks at individual benefits for signatories and non-signatories as a function of the number of signatories, he gets a figure like the one below. P(n) and Q(n) is the individual benefit of signatories and non-signatories respectively, when n countries have joined the agreement. n* is the number of signatories to the self-enforcing agreement.

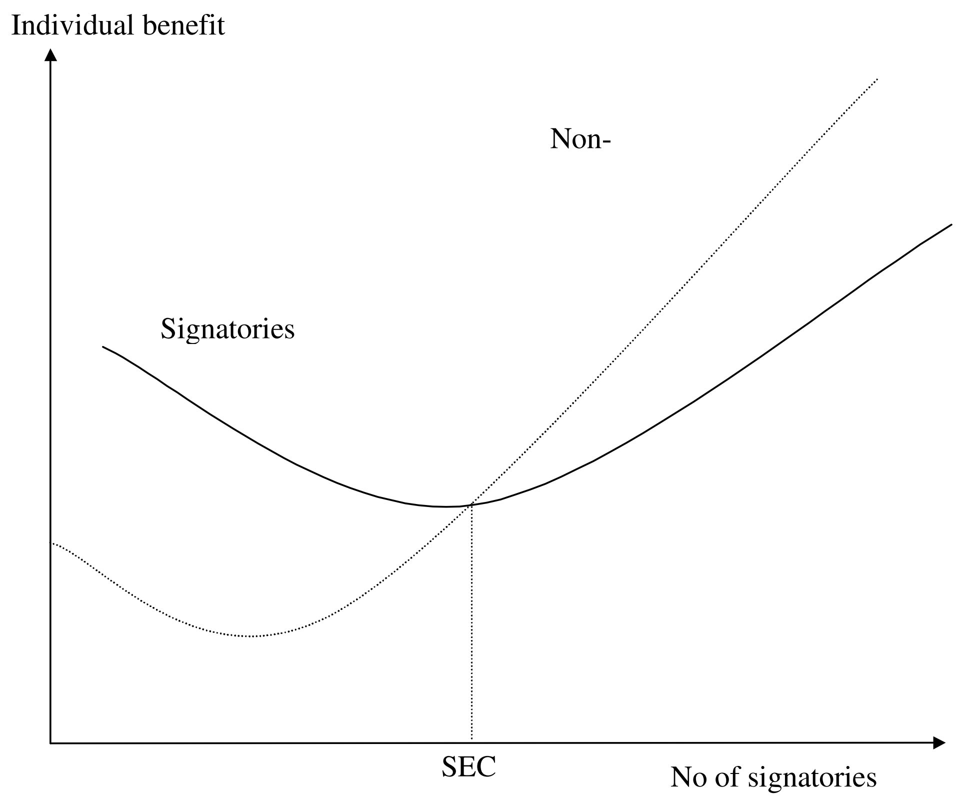

Figure 2 - The size of a self-enforced coalition (SEC)

Where the two curves meet the benefits for signatories and non-signatories is such that there is both internal and external stability to the agreement[10];

- No signatory can increase her benefit by unilaterally leaving the agreement;
  Internal stability: P(n*) > Q(n*-1);
- No non-signatory can increase her benefit by unilaterally joining;
  External stability: Q(n*) > P(n*+1).

Barrett's results are not general, but based on specific abatement cost and benefit-functions[11]. The different specifications give somewhat different conclusions, but are consistent in one respect: No self-enforcing agreement can achieve a substantial total emission reduction compared to the total emission level in the non co-operative outcome. The gain that can be achieved through a self-enforcing agreement is hence small.

[10] This concept of stability comes from literature on cartels, D'Aspremont et al 1983: "On the stability of collusive price leadership", *Canadian Journal of Economics*, 16, 17-25, quoted in Barrett (1994).

[11] Barrett uses four different sets of cost/benefit-functions: 1) Linear marginal benefits and costs; 2) Constant marginal benefits and linear marginal costs; 3) Constant marginal benefits and logarithmic marginal costs; 4) Linear marginal benefits and constant marginal costs.

It is a weakness that all countries are assumed identical in Barrett (1994). One thing is that we can not tell which countries will join. We have a co-ordination problem that might be a source of instability. Real countries are also different. In Barrett (1997) the case with heterogeneous countries is investigated. Real countries are far from identical and it is conceivable that a self-enforcing IEA between a few key countries could raise global benefits substantially. As an example, the Commonwealth of Independent States (CIS), the USA and the EU together account for about 50% of the global CO_2 emissions. (Barrett 1997)

The analysis for the non-symmetric case is however more complex. In addition to devising credible punishments that will deter free-riding, which also must be resolved in the symmetric case, the countries must agree on the obligations each country shall undertake. This means setting a target for the co-operation, and also agreeing on *burden-sharing* (Barrett 1997). In the symmetric case, with identical countries, the Nash bargaining solution require that countries undertake identical obligations (Barrett 1994). When countries are different, burden-sharing can however be immensely complicated to resolve (Barrett 1997).

Blackhurst and Subramanian (1992) exemplifies this problem; Should Brazil be compensated by the rest of the world for saving the Amazon forest, which gives environmental services to the whole world, or should the world be compensated by Brazil for the burning and cutting of parts of the forest?; Should a country's quota for carbon-emissions, in the case of an IEA to limit global warming, be calculated on a per capita basis, should the IEA aim at inter temporal equity between countries by relating the quota inversely to cumulative emissions of the last 100+ years, or should one go for an equal percentage reduction in emissions from all countries, accepting a "first-come - first served" principle? These questions have no clear-cut answers.

Two previous papers have explored self-enforcing agreements between heterogeneous countries. Hoel (1992) finds that a self-enforcing IEA consists of at most 3 countries, and Bauer (1992) finds that it has at most 2 member countries[12]. Both findings are limited by the specifications on benefit and cost functions for the countries.

Barrett (1997) finds that in a model with constant marginal benefits and linear costs of abatement, independent of the values of the parameters in the countries' benefit and cost functions, a self-enforcing agreement, if it exists, consists of at most 3 countries. If one allows for side payments between the countries in the self-enforcing IEA, it is found that a self-enforcing agreement exists but has maximum 3 members.

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[12] Hoel, M 1992: "International environment conventions: The case of uniform reductions of emmisions", *Environmental and Resource Economics*, 2, 141-159; Bauer, A 1992: "International Co-operation over Environmental goods", mimeo, Volkwirtschaftligches Institut, University of Munich. Both papers are quoted in Barrett (1997).

Barrett (1997) also investigates the more realistic case of decreasing marginal benefits from global abatement (but still linear marginal costs of abatement). He finds it necessary to limit the heterogeneity of countries to only two types, to get analytically manageable specifications. He finds that a self-enforcing IEA can have a large number of signatories, but that the increase in net benefits compared to the non co-operative outcome is negligible. This result is the same as with identical countries (Barrett 1994).

The reason for the result is however different between the cases with identical and heterogeneous countries (Barrett 1997). In the symmetric case, the conditions that must hold to get a large number of signatories to the self-enforcing IEA, are the same conditions that must hold for countries to want to abate almost as much in the Nash as in the full co-operative outcome. When countries are identical each individual country will abate more in the full co-operative outcome than in the Nash outcome. When countries differ, some will abate *less* in the fully co-operative case than when there is no co-operation, others will abate more. The self-enforcing IEA for heterogeneous countries does not improve much upon the global abatement level compared to the non co-operative outcome, but it redistributes abatement between countries. If global abatement should be substantial in a full co-operative outcome, countries with a large share of global emission should abate much even in the non-co-operative outcome (Barrett 1997).

Barrett (1997) also verifies this finding for the case of 3 big countries which together have about 50% of global emissions of some pollutant, with the rest of the countries being very small[13]. These 3 big countries can not reach a self-enforcing agreement among themselves that raise their abatement levels much above the non co-operative level. Barrett (1997) states that this is not as gloomy a result as it may first seem. Rather, if costs and benefits of abatement are so that the global abatement level should be high in the fully co-operative outcome, the countries that have a large share of global emissions should abate much even in the non co-operative outcome.

Barrett (1994, 1997) describes the process leading to a self-enforcing IEA as a two stage game, with countries first simultaneously deciding to co-operate or not, and then setting their emission levels. This is not realistic, Hoel (1994) claims. In Bauer (1993) the decision of one country on whether to co-operate or not may affect the same decision with other countries[14]. With Bauer's modelling of the process leading to an IEA, it is possible to get equilibria with many countries co-operating.

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[13] The specific example is based on the empirical fact that USA, CIS and EU account for more than 50% of the world's total CO_2-emissions (Barrett 1997).

[14] Bauer A 1993: "International co-operation over environmental goods", mimeo, University of Munich, quoted in Hoel 1994 (presumably the same paper as Barrett (1997) has quoted).

It is also possible to model the process as a repeated game. From game theory it is well known that tacit co-operation may be sustained as a perfect equilibrium of a non co-operative (infinitely) repeated game. Hoel (1994) thinks this may solve the free-rider problem. Repeated games can however have multiple equilibria. Co-ordination to reach the Pareto optimal equilibrium may be difficult, and gets worse as the number of countries goes up. This aspect probably limits the number of co-operating countries again (Hoel 1994).

A repeated game analysis is only interesting if appropriate trigger or stick/carrot strategies can lead to co-operation. Carraro and Siniscalco (1993) comments that countries' increasing their emission levels as a strategic response to other countries defection can hardly be conceived. Hence they don't approve of employing the repeated game analysis for cases of transboundary pollution.

Barrett (1994) considers the formation of a self-enforced coalition also as a repeated game. When only renegotiation proof equilibria are accepted, this modelling confirms the earlier find; The number of countries to such a coalition will be small. A renegotiation proof equilibrium is one which is preferred by all countries to any other feasible equilibrium, and in which all countries would want to punish a defector according to the equilibrium strategy (Barrett 1994, 1999).

Ecchia and Mariotti (1997) criticises the previous literature on self-enforcing agreements (i.a. Barrett 1994, Carraro and Siniscalco 1993, Heal 1994) on two accounts. Ecchia and Mariotti think that the definition of stability employed in the previous literature assumes a myopia on behalf of the countries; The countries calculate their own net benefit looking only one step ahead, ignoring the possible reactions by other countries to their choice of joining or defecting from a coalition.

The problem of joint deviations has not been considered in the previous literature, Ecchia and Mariotti wrote in 1997. As we live in a world where communication is possible and agreements may be signed, it would be reasonable to allow for the group defection (or joining) of several countries from a coalition (Ecchia and Mariotti 1997)[15].

Barrett (1999) fills the gap that Ecchia and Mariotti (1997) point out. He shows that the strategy of Getting-Even can sustain a self-enforcing agreement under certain conditions (see section 2.3 and particularly Equation 8). It then fulfils the requirements of both individual and collective rationality. Equation 8 tells that the maximum number of countries that can sustain full co-operation as a self-enforcing agreement depends on the parameter values for how the gains of co-operating and of free-riding on the agreement depends with the number of countries co-operating. Analysis of these relations reveals that full co-operation can only be sustained among many countries (globally) when the gains to co-operation are relatively small;
The aggregate gains to co-operation are (from Equation 1 and Equation 2):

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[15] These agreements would of course also need to be self-enforcing (Ecchia and Mariotti 1997).

$$N\,[\Pi_C(N) - \Pi_D(0)] = N\,(-c + dN)$$

Equation 11

The gains are hence increasing in d and decreasing in c. Equation 8 tells us that the number of countries that can sustain full co-operation as a self-enforcing agreement is increasing in c and decreasing in d:

$$\frac{b+c}{d} \geq N$$

The Montreal Protocol has nearly global participation. Barrett (1999b) has shown that the gains of this co-operation are rather small.

Botteon and Carraro (1997) investigates how the burden sharing rule may affect the formation and stability of self-enforcing coalition. For the case of identical countries they confirm the findings from previous literature that the maximum size of a self-enforcing coalition is 3, regardless of the burden sharing rule. When countries are different the situation is different (see section 3.1).

2.5 Summary

In this chapter I have looked into the incentives and mechanisms that naturally exists for countries to make and fulfil international environmental agreements. The potential gain of co-ordinated actions to deal with international externalities is the basic incentive for international environmental agreements (Barrett 1990).

Blackhurst and Subramanian (1992) have given four reasons why countries may not want to co-operate in solving an international environmental problem:

- Countries may disagree over the scientific evidence, either on the existence/seriousness of the problem, or on the efficiency of the proposed measures;
- Countries may put priority on dealing with other problems, internationally or nationally;
- Countries may disagree with the proposed cost-sharing;
- Countries may be trying to free-ride on other's efforts to deal with the problem.

Potentially high costs of negotiating agreements may also be a factor keeping countries from getting involved in many cases. Unknown, but possibly high transactions costs will enhance, especially taken together with some of the factors

Disagreement over the scientific evidence is common. During the 1972 UN Conference on Environment and Development in Stockholm, countries disagreed whether long-range transported acid rain was a serious problem. There is still some disagreement on how serious a threat global warming is. It is possible that some of the scientific disagreement is instrumental, as dealing with the actual problem may be politically very difficult in some countries. Countries with a population lacking food, adequate housing, health-services and education can hardly be expected to prioritise combating global environmental problems. Burden-sharing can however be adjusted through transfers. Side-transfers are investigated further in section 3.1.

Two types of games are used in this chapter to illustrate some possible features of international environmental problems. The Prisoners' Dilemma fits the situation where countries can get the highest total benefit by co-operating, but where each country can increase individual benefit by playing non co-operatively, independently of the others' actions. If own net costs of playing the co-operative strategy are lower than own net benefits, this model is often relevant. The Chicken Game is similar to the Prisoners' Dilemma in the respect that there are incentives to free-ride when others' play their co-operative strategy. However, if many enough tries to free-ride, individual countries have an incentive to play the co-operative strategy, to avoid "environmental disaster". The higher the number of countries contributing to the international environmental problem, the more likely is it that the situation fits the Prisoners' Dilemma, as individual countries' relative contribution to the problem is smaller. The standard Prisoners' Dilemma predicts no co-operation.

Several authors have investigated the potential of self-enforcing agreements. With such an agreement, no country wants to join nor withdraw from the agreement, given the other countries' position. Carraro and Siniscalco (1992) describes the game leading to self-enforcing agreements as a "chicken game, in which each country has an incentive to commit itself to non co-operation". A problem with the concept of self-enforcing agreements is that either the number of signatories is very low, or the environmental efforts/benefits are not significantly higher than in the fully non co-operative outcome. This conclusion is found both based on numerical analysis (Barrett 1994, 1997) and theoretical considerations (Carraro and Siniscalco 1993, 1995). Bauer (1993) (see footnote 14) have modelled the process leading to a self-enforcing agreement differently than Barrett (1994, 1997) and Carraro and Siniscalco (1993, 1995), and gets equilibria with many countries co-operating. Bauer has a sequential process for joining the agreement. This is how real IEAs are joined. Hoel (1991) and Barrett (1990) indicate that some countries will be leaders, for moral reasons.

The chance of co-operation is improved when the Prisoners' Dilemma is played repetitively. The joint management and seasonal use of shared marine resources may be real-world examples of this (although some situations may well fit the Chicken Game better).

The concept of diffuse reciprocity also brings hope of more international co-operation. Countries co-operate on many issues and on many different arenas, and the interdependence is only growing (Carraro and Siniscalco 1998). With time it will be even harder for countries to free-ride on others' efforts.

Ecchia and Mariotti (1997) bring with their model of strategic farsightedness some hope of many countries joining IEAs. Countries will however still have an incentive to free-ride, meaning here that they can avoid fulfilling their obligations under the IEA, despite having signed it.

A great deal of heterogeneity among the countries responsible for the environmental problem may make a partial solution more likely, but will not lead to its elimination (Barrett 1997).

Barrett (1999) presents “a coherent theory of international co-operation relying on the twin assumptions of individual and collective rationality”. Individual rationality implies that if all players play the equilibrium strategy, no one can do any better than to play this strategy. This is the type of rationality behind the Prisoners’ Dilemma. Collective rationality, as Barrett (1999) defines it, is that there exists no other equilibrium that all players prefer to the current equilibrium. According to this type of rationality a player reverting from the collectively preferred equilibrium would be credibly punished by the other players, back into the preferred equilibrium (Barrett 1999). Joining these two types of rationality into one type of strategy for a N-player repeated prisoners’ dilemma, leads to the conclusion that full co-operation is possible with either few countries involved, or with many countries and relatively small aggregate gains from the co-operation.

In summary one can say that generally there are natural incentives for countries to take part in international environmental co-operation, but that the natural incentives to free-ride on others' efforts are stronger, especially due to spillovers and the absence of clear property rights. Some possible features with the countries in question (moral?, "farsightedness"?), the historical situation (diffuse reciprocity between countries?), the type of environmental problem (repeated situation?) and the process of joining an actual IEA (sequential?) will influence on the chances for international co-operation. Barrett (1999) has conclusions that are rather depressing, but he points out that trade sanctions, side-payments and issue-linking, which are not part of his model, may increase co-operation. These possibilities for creating incentives for international environmental co-operation are examined in the next chapter.

3. PROMOTING INTERNATIONAL CO-OPERATION

In this chapter I investigate how international co-operation can be promoted. That means both how countries' entrance into international environmental co-operation can be promoted, and how compliance with the obligations they then take on can be promoted. Issues regarding the detection of non-compliance are a natural part of this.

Chayes and Chayes (1995) show that compliance with international agreements is the norm. International law is created by the potential violators, and hence a high coincidence between signatories' interests and "the law" is likely, Enders and Porges (1992) claim. They add that most parties can be expected to comply with the commitments in an IEA, designed by them in a co-operative game exercise, since these reflect the underlying costs and benefits of the non-co-operative game which preceded the agreement.

Blackhurst and Subramanian (1992) have pointed at four reasons why countries might not want to participate in an IEA (see section 2.2). To promote co-operation they see two basic strategies. The first is to try to "eliminate" the same reasons: Get better scientific evidence; persuade countries to change order of priority; make new proposals for burden sharing; and if a country is inclined to free-ride, try to persuade its co-operation by stressing the advantages of diffuse reciprocity.

The second basic strategy Blackhurst and Subramanian see is to create special incentives for participation in IEAs. The incentives can be either positive or negative, meaning that countries can be rewarded for participating or punished for not participating. Werksman (lecture 15.05.98) notes that "a carrot withheld is a stick", and hence the distinction may not always be relevant.

In this chapter I discuss some possible mechanisms and effects on international environmental co-operation of:

- side-transfers and burden-sharing rules
- "commitment" by one or more countries
- issue-linking

- trade-provisions and sanctions
- minimum participation clauses and limited participation in IEAs
- detecting non-compliance
- dealing with non-compliance and disputes.

The established theory of international co-operation has two pillars (major findings), which are incommensurable according to Barrett (1999):

- co-operation can be sustained by any number of countries as an equilibrium in a non co-operative repeated game with reciprocal strategies (if discount rates are not too high);
- co-operation can only be sustained by a "small" number of countries.

The "folk theorem" tell us that in an infinitely repeated game (where the players have a low enough discount rate) strategies to deter a unilateral defection are credible in the sense of individual rationality (Barrett 1999). Individual rationality imply that if all players play the equilibrium strategy, no one can do any better than to play this strategy. Collective rationality, as Barrett (1999) defines it, is that there can not exist another equilibrium that all players prefer to the current equilibrium. Hence, a collective rational agreement is renegotiation proof. Further, *if* a country defected, all the other countries would want to punish the defector rather than renegotiate or overlook the defection, provided all the other countries also did so. A credible punishment strategy requires that the countries responsible for punishing a unilateral deviation must not be able to do better, individually *or* collectively, by not carrying out the punishment specified in their agreement (Barrett 1999).

3.1 Side-transfers

Transfers between signatories of an IEA are in many cases necessary to achieve participation by those with costs of fulfilling their obligations higher than their total benefit, less the transfers (Carraro 1997a). Such transfers can come in many different forms, like access to funding of work related to the IEA, access to natural resources being protected by the agreement (e.g. marine fish), access to environmental technology (Blackhurst and Subramanian 1992), or through an international franchise agreement (Swanson 1994). The transfers could be lump-sum or flows.

Based on co-operative game theory Chander and Tulkens (1995) and Chander et al. (1999) present an IEA with side-transfers that they claim no country will be in a position to reject. With the agreement the optimal joint emissions policy is reached, and their side-transfer formula makes sure everybody is better off than in the non-co-operative outcome, and in any alternative arrangement that a sub-group of countries could adopt.

The formula for the side-transfer P_i^* country *i* pays in the co-operative outcome is:

$$P_i^* = -\left[C_i(E_i^*) - C_i(\overline{E}_i)\right] + \frac{D_i^{'}}{D_N^{'}}\left[\sum_{i\in N} C_i(E_i^*) - \sum_{i\in N} C_i(\overline{E}_i)\right]$$

Equation 12

where

- E^* is the emissions strategy in the co-operative outcome; $E^* = \{E_i^*,\ldots,E_N^*\}$;
- $\overline{E}$ is the emissions strategy in the non-co-operative outcome; $\overline{E} = \{\overline{E}_1,\ldots,\overline{E}_N\}$;
- $C_i(E_i)$ is country i's cost of restricting emissions to the level E_i
- $D_i^{'}$ is country i's marginal damages in going from non-co-operative to co-operative outcome;
- $D_N^{'} = \sum(D_1^{'},..,D_n^{'})$, the sum of the marginal damages for all countries in going from non-co-operative to co-operative outcome;
- There are N countries in total.

Each individual transfer consists of two parts:

- A payment *to* (from) each country that equals its cost –increase (-reduction) in going from the Nash equilibrium to the co-operative outcome (first term);
- A payment *by* each country as a share of the total increase in abatement costs in going from the Nash to the co-operative outcome, where its share is determined by the relative magnitude of its marginal damage compared to the total marginal damage.

The sum of all the transfers is zero. The transfer-scheme makes marginal abatement costs equal in all countries. Chander and Tulkens propose that an international agency is set up to administrate the transfers.

If a single country or group of countries reject the proposed IEA, Chander and Tulkens assume that the other countries play Nash against the potential free-riders. This will lead to a lower benefit for each country than co-operation by all can give. Hence co-operation by all will be preferred, they conclude. The alternative to the outcome of the IEA proposed is, as Chander and Tulkens (1995) see it, not a large free-riding benefit for some countries, but the payoff of the non-co-operative outcome. Carraro and Siniscalco (1998) think that increasing emissions in response to free-riding is "hardly a credible threat".

Carraro (1997) comments that Chander and Tulkens have demonstrated how all signatories to an IEA can have net benefits from the agreement through the use of side-transfers. This is a necessary requirement to achieve full co-operation. It is not sufficient, as also the incentive to free-ride must be deterred. Each country can increase their benefit beyond the full co-operative solution if they free-ride and all others fulfil their obligations (Barrett 1994)[16]. However, Chander et al (1999) demonstrate that

[16] Carraro and Siniscalco (1998) discuss briefly different models of coalitional behaviour. *Nash conjecture* implies that countries assume their decision will not affect the remaining coalition. *Coalition unanimity* is when the

with the transfer-scheme presented in Chander and Tulkens (1995), any country and any coalition of countries is best off with full co-operation.

Botteon and Carraro (1997) investigate how the burden sharing rule may affect the formation and stability of a self-enforcing coalition. They base their analysis on a world with 5 regions, each with explicit and measurable environmental features[17]. When countries are different it is possible to expand the size of the self-enforcing coalition by a system of transfers without commitment, using the Shapley value as the basis for the burden sharing rule in an IEA (rather than the Nash bargaining concept)[18]. In their special case with 5 regions making up the whole world, they also find that with a minimum amount of commitment (one country/region out of five), it is possible to stabilise the grand coalition even when the burden sharing is based on the Nash bargaining rule.

Employing the Shapley value in this manner means countries will get very different net benefits from co-operation, dependent on what time they joined. This possibly gives rise to a game between the countries of when to join (and when not to join), which may make it difficult to actually expand the co-operating coalition. Secondly, a coalition established with the aid of such transfers will be unstable, as the countries that have ended up with a relatively low net benefit will want to renegotiate.

International side-transfers might seem to be counter to the polluter pays principle (PPP), but in many cases the opposite is true. Under the Framework Convention on Climate Change and the Biodiversity Convention the industrialised countries have to bear most of the costs, including measures in the developing countries and technology transfers to these countries (Barrett 1994b). With transfers from the first world to the (second and) third the industrialised countries are now paying for their historical use of these resources. This use has been paramount for the development and welfare in the first world, at least in the case of CO_2-emissions. (Blackhurst and Subramanian 1992)

From an ethical viewpoint one wants to follow the PPP. The use of transfers, with the victim paying, are however often necessary to achieve participation in IEAs. Enders and Porges (1992, p 136) state that "….co-operation evolves from incentives for present and future actions. A notion of entitlement based on harm wrought by past actions is not relevant". International side-payments in IEAs does not

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whole coalition breaks down if one country breaks out (The Maastricht Treaty has such a clause). The countries in a coalition may consider the ultimate consequences of their possible breaking out (*farsighted strategies* in Ecchia and Mariotti 1998). The fourth model Carraro and Siniscalco (1998) mention is one of *coalition rational conjecture*, where the stated response by a coalition to a defection always equals the actual ex-post response.

[17] Based on statistical material about the real world, from P Musgrave 1994: "Pure Global Externalities: International Efficiency and Equity", paper presented at the 50th IIPF Conference, Harvard, 2-5 August 1994.

[18] The Shapley value is the sum total incremental benefit of all countries when a new country joins an agreement. Hence, with the Shapley value as the basis for the burden sharing rule, the newcomer gets this sum total as a transfer from the other countries.

come from some historical obligations, but has their basis in the incentives they make up for potential signatories to an IEA. With national environmental problems, where there is an authority to define and enforce who has the right to use a resource, it is possible to use the PPP principle. It then gives the right incentives for avoiding unnecessary pollution. The issue of efficiency is independent of whether one follows the polluter or victim pays principle.

3.2 Commitment and side-transfers

Carraro and Siniscalco (1993) aims to explain the emergence of environmental co-operation without the help of trigger or stick/carrot mechanisms through the framework of self-enforcing agreements. They note that pollution has never been used as a triggering variable, partial co-operation is a common feature of many IEAs and the use of transfers in some form is also common.

Carraro and Siniscalco (1993) investigates if some sub-group of the countries could commit to co-operate, and induce further co-operation through side-transfers to the remaining countries. The transfers must be self-financed through the increased net benefit, so that improvements are Pareto-improvements.

Commitment could stem from the diffuse reciprocity which Keohane (1986) and Snidal (1985) have discussed (see footnotes 7 and 8 in section 2.3). At the individual level a lot of behaviour is best explained through the mechanisms of social norms and conventions. Hoel (1994) believes that social norms and conventions may play an important role also in sustaining IEAs between governments. A government may "…feel uncomfortable if it breaks the social norm of sticking to an agreement [..], even if it, in strict economic terms, may benefit from being a free rider" (Hoel 1994). A government's cost of breaking such a social norm probably goes up with the number of co-operating countries (Hoel 1994). Fankhauser and Kverndokk (1992) have suggested that the OECD countries could be committed to internal co-operation on reducing CO_2 emissions[19]. Barrett (1998b) doubts whether countries really are willing to make costly commitments, pointing to the fact that a number of countries pledged voluntarily to reduce their emissions of greenhouse gases after the IPCC's 1990 report was published. None of the countries fulfilled their pledge.

Carraro and Siniscalco (1993) look at four different types of commitment in a model with identical countries:

[19] Fankhauser and Kverndokk 1992: The Global warming game – Simulations of a CO_2 reduction agreement, Memo no. 13, Dept of Economics, University of Oslo, Quoted in Petrakis and Xepapadeas (1996).

1. Only the members of the self-enforced coalition commit to co-operation ("stable coalition commitment");
2. Any new signatory in addition to the members of the self-enforced coalition must also commit to co-operation ("sequential co-operation");
3. The number of committed countries is such that the transfers needed for full co-operation are achieved ("full co-operation minimum commitment");
4. A subset of the non-co-operating countries give side transfers to the rest of the non-co-operating countries to induce co-operation (based on the increased free-rider benefit) ("external commitment").

The various forms of commitment proposed above are all less demanding than commitment by all countries, yet some of them can lead to co-operation by all[20]. How many countries that can be bribed into co-operation depends on the slope of the best-reply functions of the countries. With (near) orthogonal best-reply functions the chances for co-operative agreements are best. Then countries will not alter own emissions much due to changes in other countries emission-levels (Carraro and Siniscalco 1993).

Barrett (1994) notes that each of the original committed members to a coalition expanded in this manner, will have an incentive to withdraw from it. In other words, the new agreement is not self-enforcing. Barrett's comment does perhaps reflect his view on co-operative game-theory in general. Rasmusen (1989) also seems to hold some of the same attitudes:

> *"Co-operative game theory may be useful for ethical decisions, but its attractive features are inappropriate for most economic situations, and the spirit of the axiomatic approach is very different from the utility maximisation of current economic theory."*

Botteon and Carraro (1997) look at the case of heterogeneous countries, and conclude that when the Nash bargaining rule is used for deciding burden sharing, commitment by only a small fraction of the countries may be sufficient to induce co-operation by all.

Hoel and Schneider (1997) investigates whether a system of side-payments from committed countries to non co-operating countries reduces the incentives for commitment. A system of "joint implementation", as in the Kyoto protocol, where committed countries pay "not committed countries" to increase their environmental efforts, will give a Pareto improvement compared to no side-payments, *as long as the number of committed countries is given*. The possibility of receiving a side-payment if one does not co-operate, is a disincentive to commitment that may reduce the overall environmental effort. Hoel and Schneider (1997) finds that very likely, fewer countries commit themselves if such joint implementation is allowed for. Whether the total amount of environmental effort is lower with side-

[20] Carraro and Siniscalco (1993) have not considered repeated games.

payments, can not be determined based on Hoel and Schneider's general model, although examples in their article suggest so.

3.3 Issue-linking

While side-transfers can be used to ensure profitability for all signatories to an IEA, issue-linking can be used to stabilise the coalition of signatories. As most unresolved international environmental issues deals with some sort of public good, the way to avoid free-riding is to link these issues with co-operation on something that have an excludable positive externality for the coalition members. The incentive to free-ride on the environmental agreement is then offset by the incentive to get the excludable benefits from the other agreement. (Carraro 1997a).

Carraro and Siniscalco (1997) and Katsoulacos (1997) both investigate international linking of environmental issues with research and development (R&D) issues. Both papers show that issue-linking can be very effective for stabilising international agreements (Carraro 1997a).

Carraro and Siniscalco (1997) uses a standard model of industrial organisation. There are partial innovation spillovers, and environmental externalities. Countries that co-operate on R&D are assumed to have a larger degree of innovative spillovers than others. Firms get lower production costs with more innovative spillovers, and consumer surpluses also increase. Abatement costs may also go down with more innovative spillovers. The environmental damages depend on the global emission-level.

The sequence of decisions in the model is as follows:

1. Governments, which maximise their country's welfare, decide whether to take part in the joint environmental and R&D agreement.
2. The level of environmental effort is then decided, either jointly between the co-operating countries, or independently for all the others.
3. All firms decide simultaneously and non co-operatively on R&D expenditure and production levels.

Carraro and Siniscalco (1997) study the profitability and stability of this linked agreement. The environmental coalition is profitable but unstable, while the R&D co-operation is both profitable and stable. The linked agreement is hence more profitable than each of the two single agreements, and more stable than the environmental co-operation taken separately.

Katsoulacos (1997) comments on an earlier paper by Carraro and Siniscalco (1995) where the same model has been presented, that it is assumed governments decide whether to co-operate on R&D, while in fact individual firms make this decision. Katsoulacos (1997) further ask why, if there are benefits from R&D co-operation, why won't it take place independently of any environmental co-operation? Governments can, however, decide to jointly subsidise Research Joint Ventures (RJV's), and they can make such arrangements contingent on countries' environmental policy. Katsoulacos (1997) sets up a model for this, where firms freely choose their level of R&D and R&D information spillovers. For both these two areas the social optimum is normally higher than the actual level. It is shown that environmental co-operation can be achieved through such RJV-agreements with clauses for environmental policy.

3.4 Trade-provisions in IEAs

17 of the 127 environmental agreements that existed in 1992 had trade provisions of some kind (Mæstad 1998). The primary purpose of such trade-provisions is to avoid that trade among non-participants undermines the effectiveness of an IEA (Blackhurst and Subramanian 1992). Mæstad (1998) finds that when countries fail to implement environmental regulations, efficiency in the global economy will not be achieved unless the other countries supplement their domestic environmental regulations with trade regulations.

The use of so-called "Green trade policy" has been claimed illegitimate firstly because trade measures for environmental purposes seem to violate GATT rules[21]. It has also been claimed illegitimate since in most cases trade is not a direct source of environmental problems (Subramanian 1992); Measures should instead be aimed directly at the consumption or production activities that cause environmental degradation. Mæstad (1998) points out that countries don't always have the will or power to implement that first best policy. "…in such a second best world, where […] environmental agreements are incomplete, there are efficiency arguments for implementing trade provisions along with domestic environmental policies" (Mæstad 1998).

An example of such a situation is an agreement with limited participation to combat global warming, where domestic taxation of polluting consumption gives "leakage" effects. Hagem (1996) gives three reasons for leakages in the case of a climate agreement. One is the reduction in world prices of fuel due to reduced demand in the participating countries. This will lead to higher demand other places. Export goods produced in the participating countries with fossil fuels as factors will increase in price, leading to a shift of production to other countries. Thirdly, if limited or unilateral actions actually reduce greenhouse gases the incentive for other countries to reduce their emissions of such gases will be reduced. In principle the same three reasons for leakages will also be present for dealing with most other types of international environmental problems.

[21] Sorsa, P (1992), "GATT and the Environment", *The World Economy*, 15, 115-133, quoted in Mæstad (1998).

Often it is claimed that if an environmentally motivated (domestic) tax will give leakage effects, unilateral taxes should be set below their first-best levels. Mæstad (1998) shows that for global efficiency leakage problems should be handled through supplementing trade provisions. The efficiency of such trade provisions crucially depends upon them not leading to a trade war (Mæstad 1998).

Hoel (1999) suggests that with given groups of signatories and non-signatories to an IEA to combat global warming, the best way to handle carbon leakage is to combine the domestic environmental policy with transfers to induce non-signatories to limit their carbon emissions. Hoel (1999) repeats the finding from Hoel and Schneider, that if today's non-signatories are potential signatories for the future, the use of transfers may not be the best policy.

The Montreal protocol is an example of an IEA with trade-provisions for products directly related to the environmental problem which it tries to alleviate. Signatories have to stop both import and export of ozone-depleting substances with non-signatories, and have also to ban imports of products from a list of CFC-containing products from non-signatories (Enders and Porges 1992). The Convention on International Trade in Endangered Species (CITES) is another example (Barbier 1993).

In many instances the trade-provisions have the side effect of treating signatories more favourably than non-signatories, and are hence also an incentive for joining the IEA (Blackhurst and Subramanian 1992). Once all countries currently being major producers and consumers of the substances controlled under the Montreal Protocol seem likely to join it, a country wanting access to such substances would have to join the Protocol to get it[22]. Likewise, if a producing country wants its industry to have access to the large market for such substances it must join the Protocol. Hence the trade-provisions in the Montreal Protocol was a sufficient inducement for developing countries to join (Edgers and Porges 1992).

By creating a market for some desirable good into one with controlled participation, like the Montreal Protocol does, or totally prohibiting trade of some goods, like the CITES does, one of course also tempts people into illegal trade of these goods. The final outcome of this can sometimes be the opposite of the desired effect. Barbier (1993) investigates the illegal trade in ivory from the African elephant following the CITES ban on ordinary trade. He concluded that the ban was "at best ineffective and at worst counter-productive". Agricultural conversion of elephant habitats (or *i.a.* tropical forests) following low profitability of the "old use" of the area due to international sanctions is also a possibility.

[22] But note that the signatories have agreed to eliminate their production and consumption of the substances by year 2000 (year 2010 for low-income developing countries with a low consumption during the whole period to 2010) (Enders and Porges 1992), meaning that supplies also inside the Montreal Protocol has a clear end.

Barrett (1997a) investigates the effect credible threats of trade sanctions may have on countries' participation in international co-operation. Sanctions viewed in isolation is globally welfare-reducing, but if their use increases the supply of a public good, the overall effect may be welfare-increasing. Barrett (1997a) uses a model with stage games, where governments first make an agreement about co-ordinating their abatement levels and possible use of trade sanctions to non-signatories. Governments then decide whether they will be signatories or non-signatories to the agreement[23], and this determines their abatement levels. The countries' firms, competing in a homogenous product relevant for the environmental agreement, then set their outputs. With trade sanctions the global market will be segmented.

Barrett (1997a) finds through his model that full co-operation can be sustained for a large range of realistic parameter values, and that in equilibrium trade is not actually restricted as the threat of the sanctions is enough to assure full co-operation. A minimum participation clause is however required for the international agreement with the trade sanctions possibility. The Montreal Protocol is an example of an environmental agreement with trade provisions regarding products that are relevant for the environmental problem. It also has a minimum participation clause for the use of trade sanctions. Barrett (1997a) writes that "While the trade sanctions in the Montreal Protocol almost certainly violate the multilateral trading rules, no country has complained officially about them. This hints that [...] support for the trade sanctions in this agreement has been universal".

Subramanian (1992) states that the most important difference between the transfer and the sanctions approach is the welfare effects. Naturally, with compensation for co-operation a country is better off than with the sanctions approach. Mcmillan (1990) has shown that in a bargaining game a player's payoff is higher, ceteris paribus, the worse the opponent's payoff is in the case of bargaining breakdown. Hence the threat of sanctions in case of non co-operation makes the opponent weaker in the bargaining game. If unilateral threats of sanctions are possible, Mcmillan (1990) fears that it could significantly affect the flow of resources, especially to those developing countries which necessarily must be members of IEAs if the agreements are to be efficient. Mcmillan is also surprised that in the environmental literature it is mostly taken for granted that compensation of offenders is necessary to achieve international co-operation. In the recent history of trade policy, sanctions have been successful in promoting co-operation, according to Mcmillan (1990). Barrett (1998b) and Werksman (1996) support this view.

[23] Barrett again uses his concept of "self-enforcing agreements".

3.5 Minimum and limited participation

One would ideally like all countries that contribute to and that are affected by an international externality to participate in an IEA concerning that externality. However, typically not all participants gain directly, and side-payments, which in theory could alleviate this, have their problems. There can be substantial dead-weight losses with their administration, and countries may not be able to find a scheme of side-payments which they all consider fair (Black et al, 1993). Some countries may be trying to exploit the possibilities for free-riding that exist, as is argued within the framework of self-enforcing IEAs. Black et al (1993) state that it is then better to go for limited participation, increase the chances of reaching an IEA, and at least alleviate the problem.

Most international agreements don't come into effect before they are ratified by a minimum number of countries. This number could either be an absolute number of countries, and/or a number of countries representing somehow a certain fraction of the problem[24]. "It is clear that it would not be in the interests of a state to be bound by the obligations of an IEA unless enough other states, and in some cases *particular* other states, were bound by the same obligations", Barrett (1998) states. Most states are, for example, not interested in exposing own industry to an unilateral carbon-tax. Barrett (1998) also says that "Typically, the actual number of signatories exceeds the minimum needed to bring an IEA into force, and this suggests that the minimum participation clause may serve as a co-ordinating device". Hence, when many enough states have ratified an IEA, the cost of fulfilling its obligations falls for the remaining states. This means that a sensible minimum participation clause promotes international co-operation.

Black et al (1993) calculates the optimum threshold ratification level to maximise global benefits of an IEA on greenhouse gases (or a similar environmental problem). They assume that the terms of the IEA already have been negotiated and are enforceable[25]. All countries are then to say whether they will participate (without knowing what others have decided). When n out of N countries participate the agreement goes into effect. Only the ratifiers are committed to act. Each country knows its own benefit (b) and costs (c) of unilaterally fulfilling the terms of the agreement. For all countries $b<c$, but they expect that they will benefit from the other countries' actions. With identical countries, and r other countries participating, each country's expected benefit of <u>not signing</u> is rb, and the expected benefit of signing is $(r+1)b-c$, if the agreement comes into force.

[24] The Kyoto agreement will come into action when at least 55 industrialised countries, also representing at least 55% of the industrialised countries' total CO_2-emissions have ratified it (Kyoto Protocol to the United Nations Framework Convention on Climate Change, Article 25).

[25] To optimise global benefits the terms of the IEA, and the optimum ratification level with its expected global benefit, must be decided jointly (Black et al 1993).

The countries assume they will get the same benefit from each of the other participating countries, as from their own participation. A country's expected net benefit *before* signing depends on the belief about other countries' probability of signing. With a probability of *r* other countries signing equal to Pr[r|N-1], a country's expected benefit of signing is:

$$\Delta = b\sum_{n-1}^{N-1}(r+1)\Pr[r \mid N-1] - b\sum_{n}^{N-1} r\Pr[r \mid N-1] - c\Pr[r \geq n-1 \mid N-1].$$

Equation 13

The first term is the expected benefit of participating in an IEA that comes into effect, the second term is the expected benefit of not participating in an IEA that nevertheless comes into effect, and the third term is the expected cost of being willing to participate. The country will naturally take part if the expected benefit is positive ($\Delta \geq 0$). The optimal threshold ratification level *n** is the one that maximises global net benefit, given the values of the other variables. As the expression in Equation 13 is increasing in b, at some critical b-value the country will decide to sign.

Black et al (1993) find in their model that for global problems, like global warming, free riding is less of a problem as the total number of countries increases. This is a counter-intuitive result, depending on the assumption that costs and benefits of participation are constant for each country. As all countries gain from the others' efforts, with more countries the increased gain more than offsets the reduced probability of a country being pivotal for the agreement to come into force.

Black et al (1993) also notes that countries, depending on their expected benefit of measures, may want a different number of minimum participants for the agreement to come into effect than *n**. Hence they may be unwilling to let an international agency decide *n**. Countries with a high benefit from an international agreement will want a higher *n* than *n**, and are also likely to ratify themselves. But if they revealed their wish of a higher *n*, they would also signal that they were likely to sign, hence reducing other countries' probability of signing. Black et al (1993) concludes that countries often have little to lose from letting an international agency setting the n-rule, rather having their own preferred n-rule adopted.

A problem with Black et al's model is that there is assumed only one chance for reaching agreement. In reality countries would get at least a second chance of ratifying an IEA which did not come into effect in the first round. As ratifying means costs many countries will wait with ratification. Signalling a low benefit also increases the probability that other countries will sign.

On the opposite side of free-riding is unilateral action. It is sometimes asserted that countries should do more on their own than the non-co-operative solution demands. Morality has been used as one reason for this, and the possibility of inspiring other countries into taking responsibility by setting an example as a second (Barrett 1990). The latter idea is known as “leadership”. As an example both Finland, Sweden, the Netherlands and Norway have adopted carbon-taxes unilaterally (Hagem 1996).

Barrett (1990) asks the question of how leadership will effect the environment when international treaties are negotiated. In a two-country analysis Hoel (1991) shows that this depends on whether unilateral actions are taken before a treaty is reached and are independent of that treaty, or if it is a matter of doing more than one is committed to through an already negotiated agreement. In the first case, Hoel claims, unilateral actions may compromise negotiations and lead to greater emissions. Over-fulfilling one’s commitment to a treaty will on the other hand reduce total emissions. Hoel (1999) finds that with *given* groups of participants and non-participants, the best way to reduce leakage is for the participating countries to combine their domestic environmental policies with transfers inducing non-participants to limit their contribution to the problem.

Hagem (1994)[26] compares the costs for Norway of a domestic tax on consumption or a domestic tax on production of fossil fuels, both giving the same effects on global carbon emissions. Norway is a small country, but not an insignificant supplier of fossil fuels to the world market. She finds that reducing global CO_2 emissions through reducing the production of fossil fuels can for Norway be a cheaper way to reach her target for emissions reductions than limiting domestic consumption only.

With unilateral action or limited participation in an international agreement the efforts of these countries may to a degree be counteracted by other countries’ actions. Reductions of this kind are sometimes referred to as “leakages”. In section 3.4 I refer to Mæstad (1998). He shows that for global efficiency leakage effects of an IEA with limited participation should be handled through supplementing trade provisions.

3.6 Detecting non-compliance

As compliance is usually costly there is a continuous incentive for signatories not to comply. If non-compliance is easy to detect for the other signatories, and the potential reaction severe enough, countries will comply as long as they are able. In situations with more asymmetric information, higher costs of revealing non-compliance, and less clear or less severe punishment the chances for non-compliance are higher. (Hagem 1996).

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[26] Hagem, Cathrine 1994: “Cost-effective climate policy in a small country”, *The Energy Journal*, 15, 119-139, quoted in Hagem (1996)

Russell (1996) gives a taxonomy of monitoring and enforcement problems. His article mainly focuses on monitoring and enforcement at the national level, but most points are also relevant in the international dimension. The taxonomy is based upon three main considerations:

- What is the assumed motivation of the source of the externality for complying with the regulation (read as: complying with the provisions of the IEA)?
- What kind of discharge situation (externality) is present?
- What is the character of the regulation to be enforced?

For the first of these considerations: Are most countries voluntarily complying to the best of their ability, or will most cheat in the absence of vigorous monitoring and swift and painful enforcement action? Voluntarily compliance is very much against a fundamental assumption in economics, as it seems to downplay self-interest. For individual enterprises Russell think they might fear the public relations costs of being singled out as environmentally unfriendly enough to voluntarily comply also in the absence of potential government enforcement.

Hagem (1996) points out that it in the case of an IEA it may be very costly to deviate when all other countries in a well-defined group, like the EU or OECD, are participating. Many countries want to be part of IEAs and other international agreements in order to be attractive for investments and aid-transfers, and for products made in their country to be acceptable for conscious consumers[27]. We have earlier pointed to *diffuse reciprocity* and issue-linking as reasons for being part of IEAs and complying to them (Blackhurst and Subramanian 1992). For all these it is the case that a rather more subtle system of sanctions are feared than a straightforward enforcement by some well defined institution, just as Russell (1996) points out for the individual enterprise.

Russell (1996) has some limited data on voluntarily compliance in the US. Plants' self-reporting reveals a wide-spread lack of compliance (between 16% and 32% report of "significant violations"). Russell interprets these results as against the voluntary compliance picture. The fact that <u>self-reporting</u> tells of such high non-compliance could be taken as the opposite, namely that plants voluntarily comply *to the best of their ability*. It seems reasonable to assume that self-reporting of serious violations are correct, but without independently verified data for the enterprises which did not report of violations, the total picture is unclear.

To decide whether countries are complying with the provisions of an IEA three different mechanisms can be used, partly in conjunction. They are self-reporting, independent verification and monitoring. Self-reporting is the procedure of each country making periodic reports to the general assembly (or some other body of the IEA) on how the country has fulfilled its obligations during the period. Verification is when an agency or other body appointed by the general assembly of the IEA verifies the

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[27] Countries are not always capable of fulfilling the obligations they accept through signing IEAs (see for example Werksman 1996) , and one does wonder to what degree they know this when they sign such agreements.

information given in the national reports. There are IEAs which only use these two types of control. Monitoring is when the relevant data to decide whether a country fulfils its obligations under the agreement is collected and delivered to the relevant body under the general assembly not by the country itself, but by some agency independent of that country, (Måreng 1996).

The choice of method for documenting compliance/non-compliance depends on the amount of asymmetric information and the potential cost/value of such asymmetric information. Large penalties for non-compliance can be a substitute for tedious monitoring. (Hagem 1996)

For the second and third consideration behind Russell's taxonomy of monitoring and enforcement one must look specifically into whether, or to what degree, monitoring or inspection can detect non-compliance. Are we looking at a situation where compliance requires the installation of specific equipment?; Does the environmental policy set an upper limit on total emissions per unit time?; Is it a matter of handling and storage of barrels of highly toxic waste; etc. Most discussions of monitoring and enforcement systems have referred to situations where the actions of each single source are of independent interest, even though the result for the environment is determined by all sources' collective action. When the limitation is set in regard to the collective action, like nations getting limits on total emission-levels in IEAs, monitoring becomes more difficult due to the increasing number of sources. For some types of regulations a crude monitoring is possible through the use of materials balance (for example sulphur-emissions from fuels) or capacity limitations checks.

For the design of monitoring and enforcement systems Russell (1996) points out four especially important dimensions along which the responsible body can make their own choices:

- the probability of monitoring a source within a given period of time;
- the extent of pre-monitoring notice given (no notice = surprise monitoring);
- the definition of a violation;
- the penalty for a violation.

Together with the characteristics of the source, these factors determine the probability that the source will choose to violate its limits rather than comply over any particular time period. Examples of characteristics at the source is the attitude towards risk, and to what extent violating behaviour can be altered before monitoring starts or is finished. (Russell 1996).

It is usually neither technically nor economically possible to have continuous, precise and tamper-proof monitoring. Hence monitoring is usually performed by visits to the source by independent inspectors. The type of source/environmental externality to be regulated, and the possibility to detect a violation during a monitoring event decides how a violation should be defined in an efficient manner.

Russell (1996) notes that surprise monitoring, at the national level, may involve legal or even constitutional questions about inspectors' right to enter premises unannounced. In the case of surprise monitoring of events inside sovereign states by inspectors from outside that country, it would require that the sovereign state opened up for the possibility of such surprise visits through signing an IEA. For efficient monitoring and enforcement system design, the amount of notice given should be less than the time it would take the source to correct a violation.

Several elements need to be considered when a violation is defined. If the claim of good intentions foiled by some event more or less outside the source's control is a valid defence, moral hazards are created. Rigidly punishing every violation could on the other hand encourage concealment (if concealment is possible). (Russel 1996).

Penalties may be related to costs saved by the source by violation, to damages caused by violation, or to what one thinks it takes to encourage compliance. At the national level in the US and in Europe average penalty per conviction have been notably low. If penalties are cost-related, they must be significantly greater than one to be a good incentive, since probability of detection usually is a lot less than one. One expects rising marginal penalties (penalty for one more violation or one more unit of violation) to be part of an optimal system. (Russell 1996).

Ideally both the definition of non-compliance and penalty type and size should by given in the text of the IEA (Werksmann, lecture 15.05.98).

3.7 Dealing with free-riding, non-compliance and disputes

There may be disputes between members of an IEA about compliance, and signatories to an IEA of course regards non-signatories' free-riding as a problem.

Barrett (1998) refers to Ausubel and Victor (1992)[28] who conclude that compliance with IEAs is fairly high, "but much of it may be an artefact of the standards". Ausubel and Victor's general point is that countries comply with their obligations only because the obligations are not very heavy (Barrett 1998).They illustrate their point by noting that Norway and the Netherlands withdrew from the International Whaling Commission (IWC) in the 1950s, in a dispute over quota setting. They rejoined in the '60s, when quotas were raised.

[28] Ausubel, JH and DG Victor (1992): "Verification of international environmental agreements", *Annual Review of Energy and the Environment*, 17, 1-43, quoted in Barrett (1998)

The previous sections have shown that IEAs can be designed with mechanisms that enhance both participation and compliance. Werksmann (lecture 15.05.98) notes that a carrot withheld is a stick. Side-transfers and positive trade-provisions in an IEA may make a potential free-rider into a signatory. The possibility of revoking these positive measures from a signatory which does not comply is of course an incentive for compliance. But threats of such revokement, or other measures against free-riders and those not complying, must be *credible* (Barrett 1994). Barrett (1999) states that deterring free-riding and non-compliance is in practice the same thing.

Can sanctions be used as negative incentives, to force countries to do so and so? Sanctions can range from suspension of diplomatic/cultural/scientific contact, restrictions on financial transactions, to discriminatory trade measures on products unrelated to the environmental problem at hand. Some sanctions can also be privately organised, like a consumer boycott.

Formal game-theoretic models are neutral to the use of positive versus negative incentives. None of the existing IEAs opens up for the use of trade sanctions in unrelated products. (Blackhurst and Subramanian 1992). Signatories that don't fulfil their obligations to the Montreal Protocol may be excluded from its beneficial trade-provisions concerning related products, or its financial mechanisms (Enders and Porges 1992).

According to Werksman (lecture 15.05.98) the general attitude in the international society after the Montreal Protocol have been to assume that countries' non-compliance to IEAs are caused by poor ability, and assistance should hence be the remedy, not coercive measures. Russell (1996), contrary assumes "that all (or very nearly all) sources need considerable encouragement to comply because each is tempted by potential cost savings to violate"; Unless the expected penalty value (probability of detection and conviction times the penalty) exceeds the cost savings by not complying, sources will not comply. According to Blackhurst and Subramanian (1992) sanctions are in general not accepted as dispute resolving mechanisms concerning international agreements; Instead, there is a reliance on peer pressure and countries' willingness to pursue diffuse reciprocity when ensuring compliance with IEAs. The most important mechanisms for this are the procedures for dispute settlement (Fauchald, lecture 15.05.98).

Dispute settlement mechanisms range from negotiations, inspections, mediation, and conciliation to third parties or the International Court of Justice deciding on the matter. Strong mechanisms for dispute settlement exists for trade, investment and human rights regimes, but not for the environment. For disputes in environmental questions related to trade or investments there is a fear that the environment will be losing out, as one resorts to the dispute settlement mechanism and rules in the international agreement with the strongest mechanism. (Fauchald, lecture 15.05.98).

In the general assembly of most IEAs, decisions are made through consent. Werksman (1996) points however to decisions made by the general assembly of the Montreal Protocol, in response to Russia's reports of non-compliance, where decisions have been made against Russia's vote. Werksman thinks that the practical definition of consensus have been changed to "consensus minus one", and that this can be the start of a new practice in international law.

3.8 Summary

In this chapter I have investigated how international co-operation can be promoted, mainly through the design of international agreements. This naturally includes both measures to promote countries' entrance into agreements, and to make them comply with agreements' obligations.

For countries to join an IEA, it must be profitable for them to do so (Carraro 1997a). This can be done by rewarding countries for joining, or punishing them for staying outside (Subramanian 1992). Side-transfers may make it profitable for countries to join an IEA (Carraro and Siniscalco 1993, Chander and Tulkens 1995, Barrett 1997a). It is disputed whether the use of side-transfers can make all countries join an IEA. Chander and Tulkens (1995) present a transfer-scheme they claim will make all countries best off, and hence full participation in an IEA can be ensured. The scheme will make each individual country better off than in the Nash equilibrium, and it will make any coalition of countries better off than in any arrangement they can make between themselves. The requirement for this is however that the countries of the grand coalition respond to free riding by reverting to play Nash. Barrett (1998) states that this strategy is not normally credible. Carraro and Siniscalco (1998) neither think that going back to playing Nash, and hence increasing emissions, can be a credible threat. Chander, Tulkens et al (1999) repeats the analysis from Chander and Tulkens (1995), but neither they investigate the different groups' benefits *if* the grand coalition continues to maximise own benefit, accepting some free-riders.

Whether committed countries ("environmentally friendly countries") can bribe other countries to join an IEA through self-financed transfers has been investigated by several authors. Carraro and Siniscalco (1993) finds that different types of commitment in a sub-group of all (assumed identical) countries may, through side-transfers, lead to co-operation by all. Barrett (1994) thinks that the committed countries will have incentive to withdraw from the expanded coalition, as it will not be self-enforcing. Botteon and Carraro (1997) find that with heterogeneous countries commitment by only a small fraction may be sufficient to induce co-operation by all. Hoel and Schneider (1997) investigates the effect of side-payments from countries with obligations under an IEA to countries without such obligations, as part of a obligations trading scheme. Depending on whether countries without obligations may join the IEA in the future, they reach different conclusions on the use of side-transfers.

The opportunity to free-ride on other countries' environmental efforts stems from the (at least partly) public good nature of the environmental resource at hand. Several authors have investigated the opportunity of linking agreements on environmental public goods with agreements concerning excludable positive externalities. This way the incentive to free-ride is offset by the incentive to get the excludable benefit (Carraro 1997a). Carraro and Siniscalco (1997) and Katsoulacos (1997) find that linking environmental issues with research and development issues can stabilise international agreements.

When countries implement domestic measures (typically tariffs) to deal with an international environmental problem “leakages” often occur, reducing the efficiency of the domestic policy (Hagem 1996). Mæstad (1998) finds that to achieve efficiency, the domestic measures must be supplemented with trade provisions aimed towards the countries which have not implemented such domestic environmental measures. Mæstad makes the reservation that the trade provisions must not lead to a trade war. As supplementing trade provisions determined through an IEA usually also has the side effect of treating signatories better than non-signatories, they also make up an incentive for countries to join the IEA (Blackhurst and Subramanian 1992).

Barrett (1997a) finds that credible threats of trade sanctions may sustain full co-operation for a large range of realistic parameter values. In his model, in equilibrium trade is not actually restricted, as the threat itself is enough to ensure co-operation.

Most IEAs have a minimum participation level for them to come into force. The actual number of signatories is typically higher than this minimum level. Barrett (1998) thinks this shows that the minimum participation clause may serve as a co-ordinating device, making sure that the countries that first ratify an agreement do not have to bear the costs of fulfilling its obligations without also other countries doing the same. Black et al (1993) calculates the optimal threshold ratification value for a global environmental agreement (like for climate). In their model they find that a country’s expected benefit of joining an IEA increases with increasing number of countries totally. In other words, the effect of a country benefiting from more countries’ action more than offsets the reduced probability of a country being pivotal for the agreement to come into force. Black et al (1993) also find that countries usually have little to lose by letting an international agency set the ratification threshold level, rather have their own preferred level.

Unilateral actions by countries *may* in some cases compromise negotiations and reduce international co-operation (Hoel 1991). Unilateral actions can also reduce other countries’ incentives to deal with the environmental externality in question, Hoel and Schneider (1997) find when analysing the use of side-transfers for increased environmental efforts in other countries, like under the Kyoto Protocol’s “Clean development mechanism”.

The traditional assumption in economics is that there is a continuous incentive for countries not to fulfil their obligations under an IEA, as long as compliance is costly. Hence a need for monitoring and severe enough punishment in case of non-compliance is assumed (Hagem 1996, Russell 1996).

Today the diffuse costs of not fulfilling the obligations under an IEA may be more feared than a straightforward penalty (Blackhurst and Subramanian 1992, Hagem 1996). Examples of such diffuse costs can be a boycott of export goods by foreign conscious consumers, or a country being less attractive for foreign investments and aid-transfers.

Barrett (1998b) says non-compliance is “extremely rare”. Werksmann (lecture 15.05.98) tells that the general attitude in the international society in the last 10+ years have been to assume that countries comply as long as they are able. Assistance should hence be the remedy in the case of non-compliance, not punishment. It is necessary with a close interplay of coercion and assistance (Werksmann 1996). Chayes and Chayes (1995) claim that co-operation is sustained by an international compliance norm, and not by treaty-based sanctions (as is suggested by the theory of repeated games). They state that the authority to impose sanctions is “rarely granted by treaty, rarely used if granted, and likely to be ineffective when used” (page 32). Barrett (1998b) asks why countries then choose to comply. Is it simply customary by international law?; If compliance could not be expected, then what’s the point of international agreements (Barrett 1998b). Another view is the one held by Downs et al (1996), that countries avoid “deep co-operation”[29]. Enders and Porges (1992) say countries can be expected to comply, as the design of the IEA, which came about in a co-operative game exercise, reflect the underlying costs and benefits of the non co-operative game which preceded the IEA. If a country should join an IEA with obligations that prove too costly to fulfil (in that country’s view), they can even withdraw from it. Barrett’s (1994) concept of self-enforcing IEAs is relevant.

Free-rider deterrence and compliance enforcement are related problems and should be analysed jointly. The worst harm a signatory can do if not complying, is to behave as if it was not a signatory. Hence, if a signatory is deterred from withdrawing, it is also deterred from non-compliance – One free-riding can be deterred, compliance can be enforced free of charge. The binding constraint on international co-operation is free-rider deterrence, not compliance enforcement. (Barrett 1999).

The Montreal Protocol is seen as one of the great successes of international environmental co-operation, and a model for future IEAs. Initially it did not include a mechanism to punish non-compliance, but it had provisions that gave countries an incentive to participate. A trade sanction clause make sure signatories only trade substances that deplete the Ozone layer with each other, not with non-parties (or non-complying signatories) (Barrett 1998b). When Russia in 1996 announced that they would not be able to fulfil their obligations under the Montreal Protocol, the threat of trade sanctions, in combination with the promise of financial aid, made Russia change their mind (Werksman 1996, Barrett 1998b).

[29] Downs, GW, M Rocke and PN Barsoom 1996: “Is the good news about compliance good news about co-operation?”, *International Organization*, 50, 379-406 (page 387, referred in Barrett 1998b).

Summed up one can say that several of the mechanisms discussed here can increase international co-operation. Under favourable conditions some might even sustain full co-operation. To promote international co-operation two conditions must be met: It must be profitable for countries to join an IEA, and they must be deterred from non-compliance. To make it beneficial to join an IEA can be done both by rewarding signatories and punishing non-signatories. There is dispute over whether compliance is a norm of international co-operation, or merely a result from lack of “deep co-operation”. Barrett’s (1999) theoretical find that for global environmental problems full co-operation can only be sustained by self-enforcement if the gains of co-operation are relatively small is somewhat depressing. This is particularly because the gravest environmental problems are about the provision of global public goods: Climate change and biodiversity conservation. The limitation is to have credible punishment of free-riders. Several mechanisms discussed here have the potential to increase participation, not to full global co-operation, but perhaps to a level where most of the externality can be dealt with.

If it shall be beneficial to join an IEA, the cost of implementation must be sufficiently low. Mæstad (1998) shows that the use of tariffs may be necessary in combination with domestic measures to deal with an international externality, if the IEA has limited participation. In the next section I will look more at efficient implementation of IEAs, and particularly the Kyoto Protocol and its “flexible mechanisms”.

4. EFFICIENCY AND THE KYOTO PROTOCOL

The last two chapters have shown that:

- There are good reasons for countries to co-operate on eliminating international externalities;
- The incentives to free ride on others' efforts are in many cases stronger than the incentives for participation:
- IEAs can be designed so that individual country's benefit of participation are higher than of free-riding.

As the design of IEAs have developed over the years, they have become more and more *efficient*. That a country's obligations can be reached cost-effectively makes it easier for that country both to join and to fulfil the obligations. I will in this chapter discuss mechanisms to achieve efficiency in IEAs for global externalities, with focus on the mechanisms opened up for in the Kyoto Protocol.

A *cost-effective* international agreement achieves its goal at the lowest possible cost. An *efficient* agreement implies both that the goal is achieved cost-effectively and that the goal is optimally chosen (Hagem 1996).

The first generation IEAs concerning pollution-reductions had identical percent-reductions by all as the target. This was not cost-effective, but the information required to set cost-effective targets was not available. It was agreed to take a step in the right direction, rather than wait and do nothing. The IEAs agreed later, during the 1990s, are aiming at higher efficiency; The second sulphur protocol for Europe has specific targets for each individual country (Førsund 1994); The Kyoto protocol has built-in mechanisms that aim to achieve cost-efficiency (Barrett 1998b).

Chander et al (1999) define and characterise a global *optimum* for reductions of climate change gases. It is valid for global externalities of the public bad type in general. The first-order conditions are equality between marginal global damages due to anthropogenic influence and the marginal cost of each party's measures to reduce their influence. For *cost-effectiveness* the marginal costs of each environmental measure must not be larger than its marginal benefit, and all measures must have the same marginal cost.

Formally;

For *optimality*:

$$MC_i = MB_i \quad \forall_i$$

Equation 14

where

MC_i is marginal cost of last measure performed in country i;

MB_i is (global) marginal benefit of last measure performed in country i;

For *cost-effectiveness*:

$$MC_i \leq MB_i \quad \forall_i$$

Equation 15

and

$$MC_i = MC_j \quad \forall_{i,j}$$

Equation 16

For externalities of the private bad type, like acid rain in Europe, an optimal level of measures requires also that marginal cost equals marginal benefit for all measures. The marginal benefit of each single environmental measure can differ, even if they have the same marginal cost. For cost-efficiency, the measure with the highest gap between marginal benefit and marginal cost must always be the next to be carried out. This is regardless of whether other measures might have lower marginal costs, or higher marginal benefit. It is the *difference* between marginal cost and marginal benefit which is interesting (Førsund 1994).

Setting and implementing an optimum is difficult in practice, for several reasons:

- States must agree on how to calculate costs and benefits of possible measures/obligations (Hagem 1996, Chander et al 1999).
- The states must agree on the baseline (for example the reference emission levels that reductions are set in relation to) for the obligations. This affects burden-sharing. (Chander et al 1999).
- If states *could* agree on burden-sharing, transfers would most likely be necessary, and then new international institutions or mechanisms must be established to implement these (Chander et al 1999).
- For obligations that have a very long-term effect, like with the problem of climate change, states must agree on how costs and benefits shall be compared between generations. An efficient policy must also at each point in time include efforts towards gathering new information, as well as adaptive measures and measures to limit greenhouse gases. (Hagem 1996).

To get efficient targets in an IEA requires a very large amount of information. States usually also have an incentive to give wrong information about their costs and benefits of measures. It seems that cost-effectiveness is the best we can hope for now.

I will here consider mechanisms to increase the cost-efficiency in dealing with externalities of the public bad type only. The mechanisms I will discuss can be or are all related to the problem of climate change:

- international emissions trading (IET)/tradable quotas
- joint implementation (JI), including the "Clean Development Mechanism" (CDM).

First I will give a short overview of the Kyoto Protocol.

4.1 The Kyoto Protocol

The United Nations Framework Convention on Climate Change was one of the outcomes of the UN Conference on Environment and Development in Rio de Janeiro in June 1992. The Kyoto Protocol was agreed under the 3rd Conference of the Parties (COP-3) to the convention, in December 1997. It contains binding targets for the emissions of six major climate change gases not included in the Montreal Protocol, for industrialised countries and countries under economic transition (the countries and their quotas are defined in Annex B to the Kyoto Protocol). For the commitment period 2008-2012 the average emissions of defined greenhouse gases shall be at least 5% below the 1990 level (article 3 of the protocol). For the different countries the obligations range between minimum 8% reductions and maximum 10% increases. Carbon sequestration measures, like tree-planting and land use changes, can also give credits towards the emission targets (article 3). If a country emits less than its quota during the first commitment period, the difference can be added to its emission quota during later commitment periods *(banking)* (article 3).

The protocol opens up for different "flexible" mechanisms that can reduce the overall cost of meeting its targets. These mechanisms are tradable quotas (article 17 of the protocol), joint implementation (article 6), "bubbles" (article 4) and the Clean Development Mechanism (article 12) (Cicerone 1/98). A concrete set of rules for these mechanisms will earliest be agreed on COP-6, in November 2000 (SSB 1999).

The developing countries have no obligations to reduce emissions under the Kyoto Protocol or the Convention, but are obliged to make action plans against climate change (article 10 of the Protocol). The industrialised countries have agreed to provide "new and additional" financial resources to cover the full costs the developing countries will have in doing so (article 11 of the Protocol).

4.2 International emissions trading

Most literature use the term *emission quotas* for national emission limits specified in an IEA. If a national government allocates emission limits to domestic enterprises, it is usually called *emission permits*. Emission trading means that emission quotas or permits can be traded for other commodities, either between states or between domestic permit holders. Domestic permit holders may also be allowed to participate in international trade. (Holtsmark and Hagem 1998).

I will here consider only international emission trade[30]. I will briefly discuss both the basic mechanism leading to an efficiency gain, different design possibilities for emission trading, and some possible sources of inefficiency.

The concept of tradable emission quotas/permits was invented by Dales (1968). His starting point was a domestic pollution control authority trying to achieve cost-efficiency in a situation with asymmetric information, where the enterprises to be regulated have incentive to mislead about their costs of reducing pollution.

The parties with a relatively high cost of reducing their emissions will be willing to pay a relatively high price for an emission quota. The parties with a relatively low cost of reducing emissions will either sell their assigned quota, or simply chose not to buy a quota at an auction. For them, it will be cheaper to reduce emissions. If the market for the emission quotas is well functioning, the price paid for a quota will be equal to the marginal cost of reducing pollution for that party (given that sum of tradable quotas is smaller than pre-quota emission level). By allowing parties to trade emission quotas one ensures that measures with low marginal costs are performed before more expensive measures. (Holtsmark and Hagem 1998).

The Kyoto protocol's article 17 opens up for emissions trading between its Annex B countries. It states that the trade shall be supplemental to domestic actions to reduce emissions. The Conference of the Parties (COP) still have to define the rules to govern such trade, in particular for verification, reporting and accountability of the trading. Holtsmark and Hagem (1998) see the benefits of international quota

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[30] A Norwegian expert group, established by the government in October 1998 to give recommendations about a domestic quota trading system for climate gas emissions under the Kyoto Protocol, delivered their report to the Ministry of the Environment in November 1999. The expert group states that the most difficult issues have been the distribution of quotas between sectors, and also whether quotas should be auctioned or given away freely (NOU 2000:1). Several other countries are also considering whether some of their national emissions quota under the Kyoto Protocol shall be assigned to domestic industry and a domestic tradable quota system established (Holtsmark and Hagem 1998).

trade, but also present several arguments for limiting this trade. The cost-saving potential of allowing free quota trading among the Annex B countries of the Kyoto Protocol is estimated to be about 95%, compared to the countries fulfilling their obligations without trade (Holtsmark and Hagem 1998).

The Kyoto Protocol opens up for IET, but does not state anything about whether countries should introduce a domestic emissions trading system. If many countries nevertheless do so, governments might allow industries and companies with individual emission limits to take part in the international emission trading system (Holtsmark and Hagem 1998).

The non-Annex I countries can not take part in emission trading under the Kyoto Protocol, as a prerequisite for participation is an emission limit. When the international quota market is established, it could be beneficial for these countries to accept emission caps, and join the market. If a country can sell emission quotas for a higher price than the domestic emissions reduction will cost, it pays to join. This would reduce the leakage problem of only Annex B countries taking emission reductions. If the non-Annex B countries do not get emission limitations in the future, there is also a fear of "dirty industries" migrating there, and hence the creation of "pollution havens". (Holtsmark and Hagem 1998).

There are six different greenhouse gases whose emissions in the period 2008-2012 should be limited through the Kyoto Protocol[31]. In general quotas can vary with regard to emission measurement and the time period it is valid for. The uncertainty in measuring the emissions of the different gases has made some propose that trading should be restricted to CO_2 only. The targets set in the Kyoto Protocol is however for the cumulative emissions of "CO_2-equivalents" of the 6 gases emitted by each country, based on the "Global Warming Potential" of each gas. Monitoring difficulties may increase the chances of cheating. The emission quotas set in the Kyoto Protocol is the average for each of the years in the period 2008-2012. Other possibilities is to define a quota for a fixed year, for any defined length of time, or even repeated emissions over subsequent periods (Holtsmark and Hagem 1998).

I will now turn to some factors that could reduce the efficiency gain from IET, or even lead to lower *overall* efficiency than if the mechanisms were not allowed.

Limited participation in dealing with international public bad externalities will in general prohibit cost-effectiveness (Hagem 1996). Emissions trading under the Kyoto Protocol is to be "supplemental" to domestic measures (article 17). What "supplemental" means is not yet defined. If it will actually limit the amount of IET and JI-projects being undertaken it will lead to higher costs of implementing the Protocol (Barrett 1998b).

[31] The six gases are: Carbon dioxide (CO_2); Methane (CH_4); Nitrous oxide (N_2O); Hydrofluorocarbons (HFCs); Perfluorocarbons (PFCs); Sulphur hexafluoride (SF_6).

If agents have market power in tradable emissions-quotas this can also lead to inefficiency (Hagem 1996). United States, China and Russia had in 1992 respectively 22%, 12% and 9% of the world's CO_2 emissions from industry. These countries can possibly exercise power in the market for tradable quotas. (Hagem and Westskog 1996)

There are two ways strategic behaviour by agents with market power in emission quotas can lead to inefficiencies (Hagem and Westskog 1996; Hagem 1996):

- Agents may use their market power to influence the price of emission quotas, hence reducing their cost of the climate policy. Depending on the initial allocation of emission quotas, the inefficiency from this type of strategic behaviour can increase or decrease (Hahn 1984)[32];
- Agents may use their market power to influence the behaviour of rivals in the same industry, increasing their own market share and profit. This can be done by using the tradable quotas as instruments for monopolisation in an already oligopolistic market[33].

Note that Hahn's (1984) finding of the efficiency loss from market power depending on the initial allocation of quotas mean that the issues of burden sharing and cost-efficiency are intertwined. Hagem and Westskog (1996) discuss design features of a system of tradable quotas valid for two sub-periods, when an agent has large market power (price setter). A permit holder may either distribute emissions freely between the two periods (a "flexible" quota), or the emission level is set for each period (a "durable" quota). With durable quotas the price setter's market power is reduced, but the marginal cost of abatement in each period can differ for the price takers. With a flexible quota system the price takers will allocate abatement efforts cost-effectively between the periods. There is hence a trade off between the price setter having large market power and causing inefficiency in her quest for higher individual profit, and a cost-effective distribution of abatement efforts across periods.

If domestic industry-sectors and companies could participate in the international emissions trade rather than countries, the number of participants would increase and the problem of market power could be reduced. It would probably not eliminate the problem as some companies in the fossil fuel sector are large even globally. Further, through the use of fossil fuel taxes it is possible that some nations could exercise market power indirectly. (Holtsmark and Hagem 1998).

Holtsmark and Hagem (1998) identify another source that may reduce the cost-effectiveness of emission trading; Transaction costs. These are costs related to gathering information about trading partners, with trade negotiations and the authorities' monitoring and enforcement costs. Holtsmark and

[32] Hahn, R W 1984: "Market power and transferable property rights", *Quarterly Journal of Economics*, 99, 753-765, quoted by Hagem (1996).

[33] Hagem (1996) refers to Von der Fehr, N 1993: "Tradable emission rights and strategic interaction", *Environmental and Resource Economics*, 3, 129-191

Hagem (1998) think that these costs will be significant in the initial phase of the trading regime, but not important later.

Questions of compliance are fundamental to all IEAs. Holtsmark and Hagem (1998) think that the option of emission trading increases the *potential* for cheating, and can increase the possible environmental consequences of non-compliance, but it is not possible to say whether cheating *will* increase. Holtsmark and Hagem illustrate this with a quota seller who cheats by not reducing own emissions according to the IEA, and a buyer who will follow the rules. Through allowing trade the overall level of emissions is increased, with the quotas the buyer gets from the seller. If trade was not allowed the would-be seller emit the same level, but the would-be buyer reduces her emissions more. Another illustration: A potential buyer of quotas have high costs of compliance. She has a larger incentive for non-compliance if trading is not allowed, since trade lowers the cost of compliance.

Holtsmark and Hagem (1998) expect that the “Economies in transition” (EIT) will predominately export emission quotas to the traditional OECD countries. Since some of the EIT-countries are in a difficult economic situation, this increases the chances of cheating.

When the expected emission levels of greenhouse gases for the different countries in the next 10-20 years are compared to the countries’ obligations under the Kyoto Protocol, Russia and some of the other Economies in Transition probably have been given emission limits above their “business-as-usual” levels (Barrett 1998b, Holtsmark and Hagem 1998). This mean that they will have emission quotas to sell, and they don’t have to introduce measures to stay within their emission targets; The increased emissions from the quota buyers will not be met with reduced emissions in the seller countries. This is referred to as “hot air” trading, where the hot air is the positive difference between the emission limits and the business-as-usual emission levels. “Annex I trading lowers costs partly by lowering total abatement” (Barrett 1998b).

For the commitment period 2008-2012 hot air trading means that the emission levels will be higher than they would be if trade was not allowed. As the Kyoto Protocol allows banking of emission quotas in excess of the emission levels during the commitment period (independent of it being considered “hot air” or real emissions reductions), the net effect may not be so bad after all. (Holtsmark and Hagem 1998).

The EIT-countries probably have the lowest costs of reducing emissions, and the opportunity of buying quotas from them will reduce the Annex II countries’ costs of implementing the Kyoto Protocol. This may count when the Annex II countries’ are considering whether to ratify the Protocol[34].

[34] Annex B (of the Kyoto Protocol) lists countries with emissions limitations (approximately OECD and the countries under transition to a market economy, with EU as a separate party to the Protocol). Annex I (of the

The Economies in transition can likely reduce emissions of greenhouse gases considerably even through the use of conventional technology. If countries on the technology frontier have to take most of their emission cuts domestically, technological development can be expected[35]. Such developments could also bring about emissions reductions in countries without obligations under the Kyoto Protocol. On the other hand, the more emission trading is allowed, the cheaper it will be to implement the Protocol, and then more resources are available for research on energy efficiency and new renewable energy. (Holtsmark and Hagem 1998)

For the obligations the Annex B countries have under the Kyoto Protocol, the benefits of allowing IET will vary considerably between countries. It also depends heavily on whether trade is allowed among the Annex II countries only, or among all Annex B countries, and if there are other limitations on trade. (Holtsmark and Hagem 1998).

4.3 Joint implementation

With costs of measures differing between countries, many have pointed out the possibility of improving cost-effectiveness by allowing "joint implementation" (JI) (same as "activities implemented jointly" - AIJ) (Hagem 1996). The basic mechanism of joint implementation is that someone with an obligation to reduce own emissions, makes an investment abroad that leads to emission reductions and gets at least some if it accounted towards their own obligations (Torvanger et al 1994). I will in this section discuss the mechanism of JI, its advantages, factors that can limit the cost-saving potential of JI, as well as some methods to counter those potentially limiting factors.

Joint implementation is included in several variants in the Kyoto Protocol (Janssen 1999, Chander et al 1999, Barrett 1998b):

- Groups of countries can join together and undertake and fulfil commitments collectively, known as "*bubbles*" (article 4). EU has announced that it is a bubble" for the Kyoto Protocol obligations.
- Countries financing *projects* that reduce the emissions of greenhouse gases (or establish a sink of greenhouse gases) in other countries *with* obligations under the Kyoto, can get this credited

Framework Convention on Climate Change; FCCC) is a list of countries approximately equal to Annex B. Annex II (of the FCCC) list rich countries with special obligations (approximately OECD and EU).

[35] The possibility of technological development was one of the developing countries' arguments against plain joint implementation that ultimately lead to the creation of the Clean Development Mechanism (Werksman, lecture 15.05.98). They claimed that only the cheapest measures will be financed, and this will leave some regions without development ("Everyone will finance planting of trees in Costa Rica and no-one will pay for new plant-technology in India").

towards their own emission reduction obligations under certain conditions (article 6). This is the most common use of the term "Joint Implementation".

- Countries with obligations under the Kyoto Protocol can finance projects that reduce the emissions of greenhouse gases in countries *without* obligations, and get this credited towards their obligations, provided that investments aid development of the host country (SSB 1999) (article 12). This latter is what is defined as the "Clean Development Mechanism" (CDM). It is required that this type of JI projects are additional to what the country without obligations otherwise would have done (in the absence of the certified project). Whether sink projects should be included as part of the CDM is unresolved (Torvanger 1998).

If countries with obligations distribute their national quota to domestic actors (sectors or firms), these actors may involve in JI or CDM projects (Torvanger et al 1994).

The concept of "bubbles" will be kept out of the following discussion on JI. It differs from the other types of JI (and emissions trading) in that transfers of emission rights need not be followed by a compensation the other way. The provision was established by wish of the EU, but is not confined to them (Barrett 1998b). As long as only the EU has declared the use of a "bubble", that mechanism is less sensitive to what Janssen (1999) say is the major source of problems with JI-projects in the other sense: They are contracted between parties that fall under the jurisdiction of distinct sovereign states. The EU is a single judicial zone for many types of issues.

The most important objectives for allowing JI under the FCCC were to identify and initiate cost-effective greenhouse gas emission reductions, to support sustainable human and economic development, and encourage private capital to participate in emission reductions. JI can separate the commitment of each country from the implementation of the measures, and this reduces the cost differences of the emissions reductions among the countries. In addition to the payment, the host can gain from improved local environment, as well as getting access to new technology. (Torvanger et al 1994).

I will here first consider issues that are general for JI-projects with both Annex I and non-Annex I countries. Afterwards I will look into some issues that are special for the CDM.

According to Yamin (1996), establishing a JI system involves two steps: first, establishing a system of entitlements to emission rights and second, imposing obligations which can be fulfilled in exchange for either (1) a transfer of a tradable emissions permit, issued as part of a global tradable permit system, or (2) the implementation of a particular climate gas reducing project in a host state through the provision of financial or other assistance by the investor. The essential legal feature is to allow transfers and assignments of emissions reductions between states. "In this sense of a project based JI system it is simply a type of tradable emission quota system" (Yamin 1996).

Torvanger et al (1994) consider JI as an intermediate arrangement for when some countries have obligations to reduce emissions and some have not. If all countries in the world have emission targets to meet, tradable emission quotas should be used, as they require less control from a third party, and emissions monitoring is sufficient. Janssen (1999) draws a fairly clear distinction between JI and IET. He states that JI refers to the international *production* of emission credits involving international *investments*. In that interpretation JI and IET are complementary, as IET is a way to increase the liquidity of the emission credits produced through the JI projects.

Fully-fledged JI has never been allowed in an international context (before Kyoto) (Yamin 1996). The Montreal Protocol permits a limited form of JI, as the EU member states can operate as a bubble (Barrett 1990).

International contracts are in general difficult to enforce due to the sovereignty of the states, and the design of JI/CDM contracts must reflect this. They should be designed so that both parties have permanent incentives to voluntarily fulfil their obligations. The contracts should be *self-enforcing.* (Janssen 1999). Self-enforcement in international relations is discussed generally in section 2.4. the conclusion is that self-enforcement is difficult to achieve.

Janssen (1999) shows that when the investor-host relationship is modelled as a simultaneous one-shot non-co-operative game, with the participation constraints of both the investor and host fulfilled, it is rational for both not to enter nor fulfil such a contract. This is despite the benefit of co-operating being larger than the benefit of not co-operating. We have an inefficient prisoners' dilemma.
Janssen's matrix of the JI game is as follows:

		Investor	
		fulfils	defects
Host	fulfils	(F-L, -F+B)	(-L, B)
	defects	(F, -F)	(0, 0)

Table 2 – The prisoners' dilemma of a JI project

The first number in each pair is the host's payoffs, the second the investor's.
L = the host's gross incremental cost of the project
F = the value of the transfer from the investor to the host = the investor's cost of the investment
B = the value of the project for the investor (value of emissions reduction)

The participation constraint of the investor is

$$B\text{-}F \geq 0$$

Equation 17

The participation constrain of the host is

$$F\text{-}L \geq 0$$

Equation 18

The investor's cost of the investment must be larger than the host's cost of the project, and smaller than the value of the project for the investor ($B \geq F \geq L$). If the host or investor has risk aversion they will need an extra compensation. See section 2.3 for more on game representation of international relations.

The incentive problems between investor and host, or between COP and investor/host, can be reduced through incentive contracts for the JI projects or through institutional arrangements (Torvanger et al 1994, Janssen 1999). Torvanger et al (1994) seem to have made the implicit assumption that only the host can breach the contract. Possible remedies they propose against this is to let the contract be with a bonus payment to the host contingent of the success of the JI project. Another proposal is a "deposit-refund" system where the host pays a fee at the start of the JI project, which is returned upon verified success of the project. The contract's strength as an incentive correcting device for the host can be adjusted through the initial fee, the amount paid back and the probability of control. A deposit-refund system might be possible when the project host is in a developed country. I believe many actors in developing countries face serious financial constraints. The transfer will make it possible for them to perform the project. Withholding the transfer will hence not be an option for the investor in achieving contract compliance. This possible aspect of JI-contracts is one of them investigated in the model I develop in the next chapter.

The basic problem of JI contracts is according to Janssen (1999) to make the parties credibly commit to co-operative behaviour. One possible mechanism is to have sequential fulfilment of the contracts, similar to Torvanger et al's (1994) proposal above. Janssen (1999) suggests that the investor could function as a Stackelberg leader, making an advanced payment of part of the contracted total transfer.

Janssen (1999) analyses two different ways through which a project host can signal commitment to fulfil the international contract. The first is to let national authorities in the host country establish a mechanism by which breaches of contracts by the host are punished domestically. The size of the punishment must be so high that it allows the host to signal a credible commitment. This means the punishment must be so large that it no longer is profitable for the host to breach the contract if the investor fulfils her obligations; (from Table 2, with S denoting the punishment):

$$F-L > F-S$$

Equation 19

The punishment must be larger than the host's incremental project cost ($S>L$). This is however not likely to be common knowledge, and the host has incentives to overstate its size. Janssen (1999) therefore suggest that the authorities set the punishment equal to the value of the project's expected reduction in emissions ($S = B$; B from Table 2) (B can be found either as the value of the reduction on the IET market, or as a carbon tax reimbursement).

Janssen (1999) also investigates the host's possibilities of self-commitment through *strategic delegation*. The issue is whether the host can make a credible commitment by making a contract with a third party at the national level. The basic idea of strategic delegation is to let the player with credibility problems entitle someone to play the game on his behalf. In our context here, the host in the JI project becomes a principal on the domestic scene, making a contract with a third party, who becomes an agent. This agent is the one who will perform the actual project leading to the emissions reduction.

The structure of Janssen's (1999) proposed mechanism is as follows:

1. The potential project host makes a legally binding contract with a possible domestic agent, that is to implement a not yet agreed JI contract. The potential JI project investors know of the host's contract with the domestic agent.
2. Investor and host agree on a contract for a JI project.
3. The investor transfers the investment funds (F in Table 2) to the host. The host pays her agent the incremental cost of the project (L), as is agreed in their contract which is subject to domestic law.
4. The agent performs the project, and receives her payment (denoted Q – see below). The agent's payment is guaranteed by domestic contract law.
5. The project investor gets the emissions reduction credits transferred.

The participation constraint for the domestic agent is that $Q \geq 0$[36]. The participation constraint of the project investor is unchanged (see Equation 17), while for the project host it is now

$$F - L - Q \geq 0$$

Equation 20

Both of the mechanisms that Janssen (1999) has proposed require that the authorities in the host country can enforce its decisions and the country's laws, and has the will to do so. For some of the economies in transition or the developing countries, this remains an open question.

Different institutional arrangements for JI, apart from direct bilateral agreements between one investor and one host, are suggested by Torvanger et al (1994); A "Clearinghouse" can be established to collect information on potential JI projects and bring together investors and hosts; A "Credits Bank" for investments in JI projects can also be established, where investors make deposits and receive credits for climate gas emissions reductions from projects financed by the bank. The different institutional arrangements are discussed below, together with other mechanisms to overcome the possible problems associated with joint implementation and Clean Development Mechanism projects:

- asymmetric information between host, investor and third party (awarding emission credits)
- uncertainty of costs, as well as uncertain impact of JI-projects on overall emissions level
- transaction costs of JI
- problems deciding baseline emission levels, and controlling and monitoring JI projects

[36] It is assumed that the reservation utility of the agent is normalised to zero, representing the second best opportunity available to her.

The seriousness of these factors will depend upon (following Torvanger et al 1999):

- The parties involved: (i) the countries both have obligations under the protocol; or (ii) only the investor country have obligations
- The type of project: (a) Emissions reducing projects (energy efficiency or abatement projects); or (b) Carbon sink enhancement projects (forestation or change of agricultural practises)

Investors and hosts of JI projects will likely have private information about the project compared to the controlling body of the Kyoto Protocol. They both have incentives to overstate the emissions reduction from the project. The host wants the project to look as attractive as possible to get the contract, and the investor may get extra credits and hence has a lower cost of (seemingly) reaching her target. However, in bilateral contract negotiations with the potential host the investor has an incentive to get the emissions reductions as low as possible, to get a better bargaining situation. The Conference of the Parties can try to alleviate the situation by strict reporting and verifying procedures involving a third party or through specifying criteria for JI contracts that make the host reveal more information. (Torvanger et al 1994)

If the COP establish a Clearinghouse institution they create a market for JI projects. This will *not* in itself restrain the potential hosts from overstating the emissions reductions from their projects (as Torvanger et al 1994 claims), as larger reductions at identical cost make projects attractive. The pressure to document properly the effects of projects should however increase in competition. It is also likely that the Clearinghouse will be more competent in evaluating JI projects than any investor country of firm, or the COP. If a Credits Bank was established it too could be expected to gain high competence. Further, such a Bank could be a monopsonist, forcing the price of JI projects down due to its market power. (Torvanger et al 1994)

When the wrong partner or project is chosen, this can be referred to as *adverse selection*. It is one main type of asymmetric information problems in the economics literature. The second main type is called *hidden action*. In relation to JI projects this can be strategic actions by host countries (governments) or by enterprises in the host countries. Hagem (1996b, 1996c) and Torvanger et al (1994) investigate the effects of asymmetric information in JI-projects, modelled as *principal-agent relationships*[37].

Torvanger et al (1994) give the example of a government which lets its policies be influenced by the external funding (or possible external funding) of JI projects. Depending on the size of a particular JI project it will have local economic effects and maybe also some national scale effects. Especially for the countries without a baseline emissions target under the Kyoto Protocol can this be interesting.

[37] I assume the reader is familiar to the theory of principal-agent relationships. An introduction can be found in any intermediate level textbook in economics.

Policy changes are very difficult to monitor or control. One possible way around the problem would be to demand that national emission targets are set by all countries that want to be eligible for JI contracts (Torvanger et al 1994).

Hagem (1996c) analyses the situation where countries with abatement obligations pay a country without obligations to reduce emissions, through a "package" of JI projects. The size of the payment depends on how much the emissions are cut. Information on the cost of abatement is costly to obtain for the investor countries. She analyses both the optimal design of such a "climate contract", and what factors influence the investors' choice to get more information or not. It is assumed that the host country has private information both before and after the contract is signed. The investor can get information about the host country's *expected* costs of abatement before the contract is signed, or design a contract that gives access to the (true) cost information simultaneously with the host, after some of the abatement projects are performed. As the agreement is between (sovereign) countries, the investor can only influence the host country's choice of fulfilling the contract through the size of the transfer. If the host country finds it beneficial to break the contract, after having discovered the true costs of abatement, she will do so, and hence abstain from the transfer.

Hagem (1996c) analyses two different situations differing in when the host country finds out the true cost of abatement (alternatively, in the principal – agent terminology: two *types* of host countries):

- early, when the sunk cost of the abatement projects is relatively low;
- late, when the sunk cost of the abatement projects is relatively high.

If the abatement costs are higher than expected by the host country, she might breach the contract. In the first situation the host country's cost of breaching the contract is relatively low, in the second it is high. Hagem assumes that for the first situation, the investor must specially design the contract so that the host will not breach it. For the second situation, Hagem assumes the host's cost of breaching so high that the investor does not need to design the contract with that possibility in mind. For both cases it is found that the host country will get a profit from having private information about her type. The distribution of abatement projects between the countries with and without obligations will not be cost-effective (not same marginal cost).

If the host country finds out her true abatement costs late, the investor can get a first best contract by getting to know the host country's type before the contract is offered/designed. The distribution of abatement projects will then be cost-effective between the host and investor countries, and the investor gets all the profit. If the host country is of the type that will discover the true cost of abatement early, getting information about the host's type before the contract is offered will not be sufficient for the investor to make a first best contract. Hagem (1996c) concludes that monitoring the true cost of abatement for the host will have a higher value for the investor if the host's cost of breaching the contract is low, than when it is high.

Torvanger et al (1994) analyse the impact on global emissions if firms consider strategically to not invest in no-regrets options now, hoping to host JI projects in the future, that will give them a positive rent[38]. If a host has private information she may receive a positive rent. Torvanger et al (1994) use a two-period principal-agent model, in which firms in a country without obligations know there is a possibility of being chosen as host for a JI project in the second period. They assume there are two types of firms, one “efficient” the other “less efficient”. Each of them are considering two alternatives for investment. The cheapest investment gives less abatement than the costly one, which is preferred by the investor. For the efficient firm the cheap investment is profitable, and a no-regrets option. However, if the efficient firm has made this investment in the first period it is not interesting as a host for the JI project. This is because it is assumed that only abatement in excess of no-regrets options can account against the investor’s own emissions target. The efficient firm will in period one decide whether to invest depending on the benefit from the no-regrets option, compared to the discounted benefit of hosting the costly JI project multiplied by the probability of getting the contract. This probability is taken to be the ratio of efficient firms. Torvanger et al (1994) find that there are three possible equilibrium outcomes. Either all the efficient firms invest in the no-regrets option in the first period, no-one does, or some does. The increase in global emissions is of course higher when fewer countries carry out the no-regrets options. If the number of potential hosts is large, each host’s chances of being selected for a JI project are small, and the negative effect on global emissions due to strategic behaviour will be less. Hagem (1996b) also investigates the kind of strategic behaviour by a host firm of not investing in less polluting technology now, hoping to get profitable JI contracts in the future (not necessarily no-regrets options). She too finds that this can lead to an increase in global emissions compared to a regime where JI projects are not possible. It can also influence the calculation of the baseline emissions level for the host country.

None of the authors have considered the possibility of a host to a JI-project not fulfilling her obligations hiding under private information (i.e. the “hidden action” type problem with asymmetric information). Holtsmark and Hagem (1998) consider this as a possibility with emissions trading. I believe hidden action can be a problem also for joint implementation projects. The model I develop in the next chapter includes this aspect.

The cost of a JI project will be uncertain, as can the expected emissions reduction be. A Credits Bank with a large portfolio of projects could offer its investors lower uncertainty than the one accruing to each single project (Torvanger et al 1994). The opportunity of joint implementation means flexibility as more types of greenhouse gas reducing measures will be available. A country can reduce the overall uncertainty of measures to combat global warming through *diversification* of its portfolio of measures.

[38] A “no-regrets option” is an investment which gives a benefit under normal market conditions, even if global climate benefits are not taken into account. No-regrets investment options should not be made applicable as JI projects (Torvanger et al 1994).

The uncertainty of a specific measure may then actually be attractive if it counters the uncertainty of other measures (Torvanger et al 1994).

Bohm (1994)[39] argues that most JI projects will be relatively large, as the transaction costs of small projects will make up a substantial part of the total project cost. Barrett (1998b) thinks that transaction costs will be high, especially because it is *additional* emission reductions or sink enhancement, compared to what would otherwise have occurred, that gives credits. This will require costly analysis, and be a limit on bilateral trading. The establishment of the "Carbon Fund" under the World Bank is one attempt to reduce the transaction costs (St.meld. nr. 33). Norway is participating as an investor, with *i.a.* two Norwegian companies, and the hope is that the Carbon Fund will get a portfolio of emissions-reducing projects that the investors hope to account against their own obligations under the Kyoto Protocol. I find it likely that investors will establish relations only to a limited number of JI-hosts, get much knowledge and expertise with them, and then perform several JI-projects with each individual host. This will lower the transaction costs of each JI-project. The more similar an investor's JI-projects are, the lower will the transaction costs for each project be. In the next chapter I argue that the potential for many very similar JI-projects between one investor and one host exists, and develop a model that assumes a string of identical JI-projects between a host and an investor.

It can be difficult to calculate the emissions reduction in a particular abatement project. If the project's emissions reductions can be calculated, the *overall* emissions reduction in the host country can nevertheless be smaller due to market interactions (Hagem 1996). This is often referred to as *leakages*, and the mechanism behind them were discussed in relation to trade-provisions in IEAs, in section 3.4. With many and/or relatively large JI projects in relatively small countries, there could also be leakage effects as the projects stimulates the domestic economy, leading to more greenhouse gas emissions in the long run (Torvanger et al 1994). What is important to the COP of the FCCC when JI projects are accepted, is of course the overall effect of the projects in limiting greenhouse gas levels.

Holtsmark and Hagem (1998) question if emissions trading and joint implementation will have a positive effect on levels of greenhouse gases in the long run. The more measures that have to be performed in the developed countries, more technological development in emissions abatement and less polluting energy sources can be expected. Such new technology will also become available for the non Annex I countries (with time), possibly reducing overall levels of greenhouse gases more than with emissions trading. It is also possible that the industrialised countries' reduced costs of implementing obligations due to emissions trading means more resources are available for research in new technology.

[39] Bohm, P 1994: "On the feasibility of joint implementation of carbon emission reductions", *Research papers in Economics*, 1994:2, Department of Economics, University of Stockholm. Quoted in Hagem (1996).

The CDM is the only mechanism under the Kyoto Protocol that provides a way of including the non-Annex I countries into the efforts to reduce greenhouse gas levels, and is hence of potentially huge significance (Barrett 1998b). It is required that the emissions reductions from CDM projects are additional to what would occur in the absence of the project. This is of course very difficult to ensure as no emission limits have been set for the host countries of this type of JI-projects. There is a fear of only "paper" emission reductions being made (Barrett 1998b). According to Stavins (1998) it is also likely that the CDM projects that will be selected are those that would have been undertaken anyway[40]. Part of the reason for this is that these projects can be offered to the Annex I countries at a lower cost than other projects.

To avoid adverse selection and paper trades, the Kyoto Protocol demands that emission reductions from a CDM project must be "certified by operational entities to be designated by the Conference of the Parties". The details about this is one of the issues one hopes to resolve at COP-6 in The Hague, in November 2000. It is however clear already that the parties to a CDM project must pay for this certification. This increases the transaction costs of the project (Barrett 1998b). In addition the Kyoto Protocol demands that a share of the proceeds from CDM trades shall be used "to assist the developing country Parties that are most vulnerable to the adverse effects of climate change". Barrett (1998b) thinks this sounds like a tax, and it will also increase the costs of CDM projects, bringing down the volume of such projects being performed.

4.4 Summary

I have in this chapter distinguished between efficient and cost-effective IEAs, and looked at general obstacles to achieve either. Further I have looked at the Kyoto Protocol, investigating particularly its flexible mechanisms to reduce costs of implementation.

Cost-efficiency requires that an IEA's targets are met at minimum cost. Overall efficiency requires also that the targets are optimally set. Overall optimality is usually difficult to achieve, both due to technical and political reasons (Hagem 1996, Chander et al 1999): Costs and benefits of many different measures may need to be calculated; Burden sharing must be agreed; Targets may need to be set both in relation to uncertainty/future additional information and in relation to future generations. In light of this, cost-efficiency is likely the best to hope for.

The Kyoto Protocol opens up for several "flexible mechanisms" to increase cost-efficiency. The "Kyoto Mechanisms" are international emissions trading (IET), joint implementation (JI) and the Clean

[40] Stavins, RN: "What can we learn from the Grand Policy Experiment? Lessons from SO_2 Allowance Trading", *Journal of Economic Perspectives*, 12, 69-88. Quoted in Barrett (1998b).

Development Mechanism (CDM). IET is the international trade in emission quotas or credits for some other compensation. JI and CDM are processes whereby countries or firms with emission quotas/permits invest in foreign projects that reduce the amount of greenhouse gases. Both reduced emissions and enhancement of sinks are possible. The investors get all or some of the reduction in greenhouse gases due to the project credited towards their own obligations. The hosts for the projects receive financial and/or technological transfers. It is a requirement of CDM projects that they aid local development. Countries may also fulfil their obligations jointly, as a “bubble”, meaning that the total emissions reduction must equal the sum of their individual obligations.

The rationale behind all these mechanisms is that reducing greenhouse gas levels will have different marginal costs in different firms and areas. By separating the obligations and their implementation, marginal costs can be equalled between projects. This enhances the cost efficiency (Hagem 1996). According to calculations done by the Clinton administration, the opportunity of emissions trading between the industrialised countries will lower the marginal cost of implementing the obligations under the Kyoto Protocol with 72%, and the total cost with 57% (Barrett 1998b). It is estimated that the total costs for Norway, of fulfilling the obligations under the Kyoto Protocol, can be reduced by 2/3 through joint implementation (St.meld. nr. 29)[41]. According to St.meld. nr. 33 the Kyoto mechanisms can lead to a common price on emissions of greenhouse gases in the industrialised countries, and that measures with the same cost-level will be accomplished in the developing countries.

The rules for the use of the Kyoto Mechanisms have not been agreed upon. In Buenos Aires (COP-4 1998) the parties agreed a “work programme on mechanisms” containing 142 issues. This should, according to Torvanger (1998), resolve “Everything you ever wanted to know about the flexibility mechanisms”. Norway hopes that the rules will be decided during COP-6, in Hague in November 2000 (St.meld nr. 33).

There are several factors that can limit the cost-reducing potential of the Kyoto mechanisms, or even lead to lower cost-efficiency than if the flexible mechanisms were not allowed.

Hagem (1996) and Hagem and Westskog (1996) have analysed the possible effect of actors having power in the market for tradable quotas. They may influence the price of emission quotas to their own benefit, or use tradable quotas as an instrument for monopolisation. Actors’ market power can be influenced by the initial allocation of quotas, and hence the issues of efficiency and burden sharing are not separate (Hahn 1984). Transaction costs will probably reduce the efficiency in an initial phase of an emissions trading regime, but not when it is well established (Holtsmark and Hagem 1998). Bohm

[41] “Norway have entered climate-related projects in China, Mexico, Poland, Burkina Faso and Costa Rica, and will probably sign similar agreements on projects in India, Slovakia and Barbados” (Aftenposten interaktiv, 21 January 1998). Norway has specifically financed a 35 million NOK investment in modernising and renovating a coal power plant in China, hoping to be able to credit the CO_2-emissions reduction towards their Kyoto obligations (SSB 1999).

(1994) and Barrett (1998b) think that the transaction costs of joint implementation projects will be high. I assume investors to JI-projects will establish solid relationships with a very limited number of hosts, get much competence on co-operation with these, perform several JI-projects with each, and hence reduce the transaction costs of each individual JI-project.

Different views exist on whether joint implementation is an intermediate tool, only interesting until all countries have obligations under the Kyoto Protocol, or as a permanent complement to emissions trading. Janssen (1999) defines joint implementation to be the production of emission credits through international investments, and international emissions trading as a means of efficient liquidation of these credits.

Contracts on JI and CDM-projects will be between parties under different jurisdictions. Janssen (1999) states that hence they should be *self-enforcing*. The basic problem with such contracts is to make the parties credibly commit to co-operation, and he suggests two ways it can be achieved for the project host. One is to have national authorities establish a (domestic) mechanism to punish contract-breaches. The other is to use *strategic delegation*. It involves to make a contract with a domestic third party, which will perform the actual investment project. The contract must be known to potential investors, and set up before the JI-contract itself is made.

Torvanger et al. (1994) also propose mechanisms to make the host comply with the JI-contract, involving that some or all of the transfer to the host is withheld. This can be directly, or trough a deposit-refund system where the host pays an initial fee to be refunded together with the transfer if the contract is fulfilled. For many JI-hosts in developing countries I believe the transfer from the investor is necessary to make a host able to perform the project. Withholding the transfer to achieve compliance will of course not be an option if the host already has received it.

Private information held by the host of a JI project can be used advantageous for her (Torvanger et al 1994). Both “hidden action” and “adverse selection” type problems are possible. Holtsmark and Hagem (1998) think that the potential for cheating increases with emissions trading, considering the case of a quota seller that will not actually reduce own emissions in accordance with the sales of emission quotas (hidden action).

Hagem (1996b, 1996c) analyses some situations with asymmetric information between host and investor of JI-projects. Hagem (1996b) looks at the case of a potential host abstaining from investments today, hoping for profitable JI-projects in the future. This may lead to overall levels of greenhouse gases being higher than if joint implementation is not allowed. Hagem (1996c) considers a case with one investor and several hosts. If a host finds her cost-level to be high, she may breach the contract and abstain from the transfer. A host’s expected cost-level (before the contract is made) is private information, as well as her true cost-level (which is revealed during the project-period). At a cost the investor can reveal this private information. Hagem (1996c) investigates how the contract should be designed, and when paying for additional information is beneficial to the investor, depending on the type of host (high or low cost).

None of the authors cited here have considered hidden action problems in established JI-contracts. I believe this type of problem is likely to occur, and the model I develop in the next chapter includes this aspect.

The overall effect of a JI-project is often uncertain, as it can be reduced due to *leakages* (market interactions) (Hagem 1996). There are also other sources of uncertainties, but they can be averaged out for investors through the use of a Credits Bank engaging in a portfolio of projects. Creating a market for JI-projects by establishing a Clearinghouse institution will also reduce some of the above mentioned difficulties (Torvanger et al 1994).

Holtsmark and Hagem (1998) ask if enough technological development will take place if the use of the flexible mechanisms is extensive. Less flexibility means more measures must be performed in the industrialised countries, driving technological innovation. New technology can have a positive long-run effect on the levels of greenhouse gases that outweighs the current savings of emissions trading.

In 1990 the OECD countries contributed to 38% of global CO_2 emissions. According to IPCC's mid-range scenario[42] it will shrink to 30% by 2025 and 22% by 2100. The developing countries must therefore be induced to limit also their emissions in the future, if significant global emissions reductions shall be achieved. However, the Framework Convention on Climate Change (FCCC) and the "Berlin Mandate" (from COP-1 in Berlin) state that the developing countries shall not carry any of the cost of the measures to combat climate change. (Hagem 1996).

The Kyoto Protocol has not yet been ratified by enough countries to enter into effect. It is expected that the developing countries must accept some obligations to get enough industrialised countries (especially USA) to ratify the Kyoto Protocol (Barrett 1999 and St.meld. nr. 33). Major developing countries like China and India are against this, and they also want to limit the use of the flexible mechanisms (Torvanger 1998). The use of the flexible mechanisms of the Kyoto Protocol are required to be "supplemental" to domestic actions to reduce the levels of greenhouse gases (article 6 of the Protocol). Barrett (1998b) find this requirement "a twisted logic"; A restriction on emissions trading will harm the environment by elevating between-country differences in marginal abatement costs and magnify the leakage problem (Barrett 1998b). What "supplemental" means is however not yet defined. The EU supports a quantitative ceiling on the use of flexible mechanisms "to ensure that the majority of emissions reductions are met domestically" (Barrett 1998b's quote of EU parliament resolution from September 1998). EU want to limit the use of the flexible mechanisms to force technological progress,

[42] IPCC = UN's Intergovernmental Panel on Climate Change. 1995: The Second Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.

and also to limit “hot air trading” with Russia/Eastern Europe (Torvanger 1998). “Hot air” is the popular term for the part of these countries’ emissions quota which are above their business-as-usual prognosis, and hence probably can be traded without being met by additional domestic measures. Emission levels *below* the quotas set in the Kyoto Protocol will however be allowed transferred to the next commitment period, meaning that hot air is a choice of trade now or “free credit” later. (Holtsmark and Hagem 1998). Barrett (1998b) thinks that if the “hot air” provision had not been created for the Economies in Transition, it is likely that the other Annex I countries would have insisted on smaller reductions in their emission levels, due to higher implementation cost.

Some developing countries see a potential benefit in selling emission quotas and in getting access to new technology through JI-projects. Then they need a baseline emissions target. As long as they don’t have obligations under the Kyoto Protocol, one alternative is to take on voluntary commitments. Argentina and Kazakhstan have announced that they will take on voluntary commitments for the first target period (2008-2012) (Torvanger 1998). When Annex I countries impose measures to reduce their emissions of greenhouse gases, comparative advantage in such industries shift towards the non-Annex I countries. The reduced demand for fossil fuels in Annex I countries will also make the world price lower, which additionally stimulates the greenhouse gas intensive industries in the developing countries (Barrett 1998b). In addition to leakages, this could even lead to “pollution havens” (French 1993, Hagem 1996). It is important to set emission limits for the developing countries to avoid these effects.

The emission limits in the Kyoto Protocol are for the period 2008-2012. How future limits will be is not yet decided. As many of the possible investments to reduce emission levels for the current commitment period can have very long lifetimes, investors’ beliefs about future emission limits matters a lot (Barrett 1998b); If they expect low limits, long-term carbon-saving investments are more attractive than if the opposite is expected. However, even if banking of excess emission reductions this commitment period are allowed by the Kyoto Protocol, states will probably be reluctant to overshoot their targets (Barrett 1998b); Once the investments leading to overshooting of the targets were done, the cost is sunk, and the country’s bargaining position about next periods’ targets will be weakened.

For the overall level of abatement prescribed by the Kyoto Protocol to be achieved cost-effectively abatement must be undertaken in the non-Annex I countries. This can potentially be achieved by the Clean Development Mechanism, but only under the most favourable of assumptions. It seems more likely that emission caps will have to be negotiated for the developing countries. This does not imply that they need to pay for this abatement themselves (Barrett 1998b). Also Chander et al. (1999) and Helms (1999) heavily stress the need to include all countries when combating global warming. The reason for broadening participation is not so much to redistribute costs, as to lower the total bill (Barrett 1998b).

It is perhaps unrealistic to get emission caps for the developing countries within this commitment period. For the next commitment period it is important that the emissions reduction target involves reductions in the non-Annex I countries. It will reduce the problems with the flexible mechanisms of the Kyoto Protocol. These problems are particularly big when countries without targets are involved. For this commitment period it is important that the rules for the use of the Kyoto mechanisms reduce the problems due to asymmetric information and sovereignty of states as much as possible.

It is clear that the Kyoto mechanisms have a potential to lower the costs of measures to combat climate change by equalising marginal costs across countries. Major obstacles to achieve this cost-saving potential are, apart from the parties to a contract being under different jurisdictions:

Emissions trading	**Joint implementation / CDM**
▪ Market power ▪ Transaction costs ▪ Asymmetric information opening up for hidden action ▪ Limited participation in trading ▪ "Hot air"-trading	▪ Transactions costs ▪ Asymmetric information opening up for adverse selection and hidden action ▪ "Paper trades" due to no emission-level baselines for developing countries ▪ Limited participation ▪ Leakages

Table 3 – Obstacles to realise the cost-reducing potential of the Kyoto mechanisms

For many JI-projects in developing countries, I expect that the host must receive (most of) the transfer before project-measures are performed, due to the host's lack of financial resources. Threatening to withhold the transfer if the JI-project fails will then not be a possible way for the investor to force compliance. In the next chapter I develop a model that includes this assumption. Further it is assumed that a string of very similar JI-projects are possible between one single host and one investor. This should cut the transaction costs of each single project considerably. The third major assumption is that hidden action by the host is possible; She has private information and there can be other sources to project failure.

5. REPEATED INTERNATIONAL CONTRACTS UNDER ASYMMETRIC INFORMATION AND UNCERTAINTY

5.1 Introduction

In the 3 previous chapters I have looked into existing literature concerning three main themes. The first was what natural incentives that exist for countries to engage in international environmental co-operation, and the second how such co-operation can be improved/supported. The third theme was mechanisms to facilitate efficient implementation of countries' obligations under an IEA, with emphasis on the flexible mechanisms in the Kyoto Protocol. *International emissions trading* and *Joint implementation* can potentially lower the overall cost of combating global warming, but there are several obstacles in the way.

In this chapter I develop two models of possible joint implementation relationship between a host and an investor, that I think will be appropriate for some cases. It has the following starting points:

- High transaction costs will be an obstacle to JI-projects. Investors will try to reduce these. One possible method is to concentrate on few potential hosts, get much knowledge and competence in dealing with these, and performs several JI-projects with each of them. My model is therefore of a repeated relationship between a host and an investor. The JI-projects in each period are assumed identical for simplicity, but that assumption may also fit some cases fairly good. As an example, Russia today rely on inefficient coal or diesel/oil power plants for electricity supply in many areas. Most of these plants are probably quite similar, and it might be possible to get a contract with the national authority responsible for (most of) them.

- The projects with the lowest marginal cost of reducing climate gases will be in developing countries and the "Economies in transition" (former Soviet Union/Eastern Europe). These regions are in general politically and economically unstable, and with much corruption and crime. I believe (like Holtsmark and Hagem (1998) does for IET-contracts) that this increases the potential for cheating by the project host. My model therefore includes private information on the part of the host, as well as other possible sources of project failure, opening up for *hidden action* by the host. In "the model with control possibilities" I assume that the host can reduce the chances of project failure due to uncertain external sources, but at a cost.
- JI-project hosts in developing country likely face severe financial constraints. They may therefore need the transfer from the investor to be able to perform the JI-project. My model assumes that the host receives the transfer at the start of a JI-project. While this makes the host able to perform the project, it takes away the single most powerful measure the investor has to ensure compliance with the agreed contract: Withholding the transfer in case of breaching. In my model this leaves the investor with only one tool to influence the host's compliance: The threat of not offering new JI-projects in the future.

Formally, the models are of infinitely repeated principal-agent relationships. The principal and the agent can be countries, industry-sectors, firms or others. My starting point is to investigate JI-contracts, but other interpretations are possible. IET is another, particularly when the traders delegate quotas down. Another example might be where the agent is a national park administration, and the principal wants changed management of the area or of certain animal species in the area. The basic point is that the principal can not directly affect the situation in the agent country, but the agent can. What the principal wants I denote as *a change in the state of a natural resource* in the agent country. For this to happen *a change in the agent's behaviour* is required. Changing the behaviour has a cost for the agent. If the agent does not change behaviour, the principal observes what she considers as *misuse* (project failure). The principal may offer a one-period contract, involving that the agent changes her behaviour in the period, and the principal will compensate by making some sort of transfer to the agent[43]. If the agent accepts, she receives the transfer from the principal at the start of the agreement-period. The transfer may be viewed necessary for the agent to be able to change her behaviour.

[43] The transfer in a JI-contract may in principle be of any form, including technology transfer, grants, debt reductions, or giving the agent the status of most-favoured trading partner.

The principal can not directly observe whether the agent does change her behaviour, but only the state of the resource. There is hence asymmetric information. In addition to, and independent of the agent's behaviour, something or someone else may also influence the state of the resource which the principal is interested in. This is modelled as a certain probability of misuse, regardless of the agent's actions. Uncertainty is hence present. At the end of one period the principal will decide whether the agent shall be offered a new contract for the coming period. Due to the information asymmetry the agent may be tempted to cheat, stating willingness to change behaviour, but not actually altering it. The possible payoffs from one period to another are assumed constant, and the transfer to the agent is made at the beginning of a contract period. The principal can therefore only try to give the agent the right incentives through the choice of how often a contract is offered.

The strategies the actors employ are assumed to be Markov strategies. A Markov strategy is a history-dependent strategy. Behind the use of Markov strategies lies the assumption that the most recent action will have the greatest impact on current action (see Maskin and Tirole 1988[44]). The state of the economic system is summarised in a state-variable, and the current state is assumed only dependent on what happened in the last period. Hence it is made explicitly state-dependent. The models are based on Clark (1992), and his model of the relationship between banks and sovereign borrowers in the international credit market. The basic model here is an application of his model to a new issue, while the model with control possibilities is an extension of his model.

In addition to the basic model described above, a version is included in which the agent can influence the frequency or probability with which other elements influence the state of the natural resource. In many real situations the possibility of exerting control is indeed present. Efficiency and the cost of control may vary a lot though. How the use, cost and efficiency of such measures influence the agent's behaviour towards the principal in our setting is interesting. This is investigated in the "model with control possibilities".

Several states may be identified in the models. The expected payoff in each state does not change through time, no learning takes place, and none of the players builds a reputation. There is hence no structural or informational dynamics. The state of the system in the next period will only depend on the current state and the current actions (given by the strategies' state-dependence). Due to this, and the element of uncertainty introduced earlier[45], the game can be described as an infinitely repeated stochastic game constrained to follow a first-order Markov process (Clark 1992). We assume that both players are rational, and that they seek to maximise the present value of their expected payoffs.

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[44] Maskin and Tirole 1988: "A theory of dynamic oligopoly I: Overview and quantity competition with large fixed costs", *Econometrica*, 56, 549-569, quoted in Clark 1992.

[45] The probability for other elements in the agent country to cause misuse of the natural resource must be different from 0 and 1 for uncertainty to be present, and the problem to be interesting.

I give comments on "internal" aspects of the models within each section dealing with that model (section 5.2 for the basic model and section 5.3 for the model with control possibilities). In section 5.4 I discuss how the models can be relevant for the implementation of the flexible mechanisms in the Kyoto Protocol. I sum up the chapter in section 5.5.

5.1.1 Definition of strategies

Let *p* represent the probability that the principal offers the agent a contract, and let *i* denote the possible states of the system. A Markov strategy for the principal is a state dependent rule $p_i \in [0,1]$ which selects a probability for offering a contract to the agent for each of the states. A Markov strategy for the agent is likewise a state dependent probability of acting in accordance with the principal's wishes; $a_i \in [0,1]$.

5.1.2 Definition of an equilibrium

A stationary equilibrium consists of a set of strategies for each state (a_i, p_i), such that p_i maximises the principal's discounted expected payoff, given a_i and the current state, while a_i maximises the agent's discounted expected payoff, given p_i and the current state.

If both players do the best they can, given optimal actions of the other player, we have a Nash-equilibrium. Neither player needs to know what the other person will do, but they will have a subjective expectation of it. In a Nash equilibrium the beliefs are correct, and each player employs a strategy (pure or mixed) to maximise expected payoff.

5.2 Basic model

5.2.1 The game

The game is between two players, the principal (P) and the agent (A). The players are assumed to be risk-neutral[46], and the economic environment is taken to be stable. The principal wants the agent to change her behaviour, and may to this purpose offer a one-period contract to her. If the agent promises to change her behaviour in the period, the principal will compensate her through some sort

[46] Risk-neutrality implies that the actors maximise expected payoff. Risk-sharing will hence not be a feature of the equilibrium.

of transfer. The agent will always accept the contract and immediately receives the transfer. The agent then decides whether or not to change her behaviour in that period. In either case other elements in the agent country, beyond the control of the agent, will (in the principal's view) cause misuse of the resource with a probability $\gamma \in [0,1]$. This probability is common knowledge to both the agent and the principal. The principal can not observe actions in the agent country, but only whether misuse of the resource has taken place. The agent makes her decision to break or keep the contract before any misuse have had a chance to occur. If the agent does not change her behaviour, the principal will find the resource misused, regardless of other factors. When the period is over, the principal again considers whether to offer the agent a one-period contract, and the game is repeated.

The principal's benefit from proper use of the resource outweighs the costs associated with the transfer decided in the contract. The benefit of the transfer is larger for the agent than the costs of changing behaviour. There is an incentive for the agent not to change behaviour and hence increase the one-period net benefit. As elements in the agent country will cause misuse of the resource in some periods anyway (assuming the probability is larger than zero), the agent can blame misuse upon them. How often the agent chooses not to keep her part of a contract will clearly depend upon the frequency by which the other elements cause misuse of the resource.

5.2.1.1 States and Strategies

All relevant information concerning the past history of the system is summed up in the state variables. There are three different states here:

State 1) Contract was offered, and the environmental resource was not misused (according to the principal's definition of misuse).

State 2) Contract was offered, but the agent did not change behaviour, or alternatively the agent did change behaviour, but the environmental resource was misused by others in the agent country[47].

State 3) No contract was offered. The agent will not change behaviour as it would mean an economic loss to her.

5.2.1.2 Expected payoffs

The one-period payoff in state (3) is taken to be a reference value of zero for both players. The expressions are written in such a manner that all variables have a positive value. The amount of misuse of the environmental resource is ignored. Hence costs or benefits are fixed sizes. The assumptions we have made so far lead to the following expression for the present discounted value of the expected payoffs in each state for the principal (denoted G_i):

---

[47] The principal cannot distinguish the two alternative situations described, and hence they can neither constitute separate states.

$$G_i = (1-p_i)\delta G_3 + p_i\{a_i[(1-\gamma)(B-F+\delta G_1)+\gamma(-F+\delta G_2)]+(1-a_i)[-F+\delta G_2]\}$$

Equation 21

where i=1,2,3.

As this state-dependent expected payoff for the principal is independent of which period it concerns there is no need to pay attention to period number or time in any other notation.

δ is the principal's discount factor ($\delta \in \langle 0,1 \rangle$).

γ is the probability that someone in the agent country will cause misuse of the resource independent of the agent's behaviour ($\gamma \in \langle 0,1 \rangle$).

B is the benefit to the principal if the resource is not misused.

F is the principal's cost of making a transfer to the agent.

It is assumed that (B-F)>0.

δG_3 is the principal's expected discounted payoff (the continuation payoff) from not offering a contract, while the term in braces in Equation 21 is the expected discounted payoff from offering a trade contract. The relative magnitudes of these two terms determine the principal's policy regarding offering contracts to the agent. The two terms themselves are also affected by the principal's policy since they depend on the expected payoffs (the G_i's).

The present value of the expected payoff for the agent is given by

$$H_i = (1-p_i)\mu H_3 + p_i\{a_i[(1-\gamma)(T-L+\mu H_1)+\gamma(T-L+\mu H_2)]+(1-a_i)[T+\mu H_2]\}$$

Equation 22

where μ is the agent's discount factor ($\mu \in \langle 0,1 \rangle$);

T is the benefit to the agent of receiving the transfer from the principal[48];

L is the cost (Loss) to the agent of changing behaviour;

It is assumed that (T-L)>0.

The relative magnitudes of the two terms in square brackets in Equation 22 determine the agent's strategy as to whether use the environmental resource in the usual manner or not.

A representative round in the game can also be described in a game tree. In the figure below the players' expected payoffs are in parentheses (P, A).

[48] The principal's cost of making the transfer is F. If the transfer is a lump sum, and there are no transaction costs, F and T are equal. If the transfer comes in another form, they could well be different.

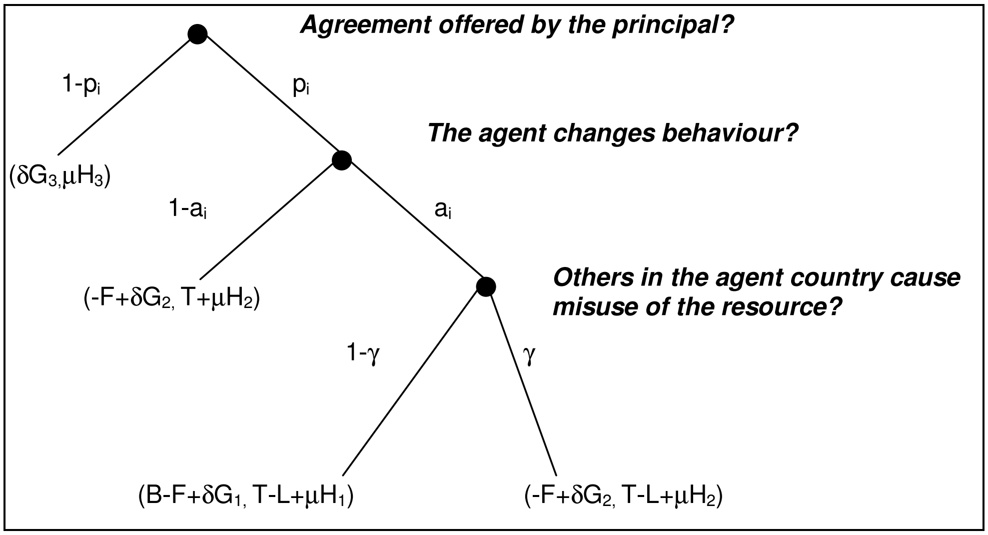

Figure 3 - Game tree excerpt for the basic model, with continuation payoffs (P, A).

5.2.2 Solution to the game

For the game to potentially have an equilibrium other than "no contract", it must have a probability for continuing larger than zero in each period. This is easily verified by backwards unravelling. Here we have assumed infinite repetition. There are two possible Markov Perfect Equilibria for this model; One in pure strategies where there is no contract, and one in mixed strategies with contracts at least in some periods. The proof of the solution is left to the appendix, section 7.1.1.

5.2.2.1 Equilibrium (1):

Given that the following conditions are fulfilled:

a) $$B \geq \frac{F}{1-\gamma}$$

Equation 23

b) $$T > \frac{L}{1-\gamma}$$

Equation 24

c) $$\mu \geq \frac{L}{T(1-\gamma)}$$

Equation 25

the strategy of the agent will satisfy

$$a_i = \frac{F}{B(1-\gamma)} \forall i.$$

Equation 26

The strategy of the principal will satisfy

$$\mu p_1(1-\gamma)T - \mu p_2\left[(1-\gamma)T - L\right] - L(1+\mu p_3) = 0$$

Equation 27

5.2.2.2 Equilibrium (2):

If any of the conditions (a-c) in Equilibrium (1) are not fulfilled,

p_i=0 and a_i=0 for $\forall$i.

5.2.3 Comments to the basic model

The game-theoretic model presented here can give two possible types of equilibria. In Equilibrium (2) the principal offers no contract, and the agent will not change behaviour. Equilibrium (1) depicts the type of equilibria where a contract may be offered at least in some periods, and the use of the resource may be compatible with the principal's wishes at least in some periods.

Notice that Equilibrium (1) permits multiple equilibria, since many combinations of values of p_1, p_2 and p_3 can satisfy Equilibrium (1)'s requirements. With this type of equilibrium there may be several periods in which contracts are offered, and several periods with no contract offered, all within the same equilibrium. The sequence of periods with and without contracts is determined endogenously in the model, based on the players' strategy decisions.

5.2.3.1 Comments to the conditions of Equilibrium (1)

Equilibrium (1) only exists if the three conditions (a-c) are fulfilled.

Condition (a) states that the principal's expected one-period payoff when the agent changes behaviour to accord with the principal's wishes must be non-negative. If it is less than zero, for example due to others in the agent country causing misusing of the resource too frequently, the principal will not offer a contract to the agent.

Condition (b) states that the transfer the agent receives in a period with a contract must be larger than the cost of keeping the contract, given that no-one else has misused the resource. If the condition is

not fulfilled, the agent will have a negative expected payoff, even when the principal uses the strategy where she is most willing to excuse possible misuse by the agent.
Also, γ has to be low enough for the principal to know that the agent will not always cheat. The possibility of cheating increases as γ increases, and when γ is too large the principal is not willing to offer a contract as it knows that the temptation to cheat becomes too big.

Condition (c) states that the agent must have sufficient regard for the future. If future income is valued less by the agent than indicated by (c), her expected payoff will be negative even with the highest frequency of offered contracts fulfilling Equilibrium (1). The higher the loss of not using the resource, the higher the probability of other groups misusing the resource, or the lower the benefit from the transfer is for the agent, *ceteris paribus*, the higher it must value future gains for Equilibrium (1) to exist.

The principal has an expected payoff of zero in all states in Equilibrium (1). This is the reason why the conditions and equilibria are independent of the principal's discount rate (δ).

5.2.3.2 Comments on the agent's strategy in Equilibrium (1)

Let us now turn to the implications of the agent's strategy in Equilibrium (1). The agent's strategy is given by Equation 26:

$$a_i = \frac{F}{B(1-\gamma)} \qquad \forall i$$

It is the same in all states, as the agent in all states faces the same horizon of possibilities, *given* that a contract has been offered. If no contract is offered, the agent will use the resource in the traditional manner, and $a_i=0\ \forall i$. Equation 26 is hence the strategy conditioned upon a contract.

The costlier it is for the principal to make the transfer to the agent, or the less the principal values the environmental resource, the more often must the agent keep her part of the contract. The more likely the other groups in the agent country are to exploit the environmental resource, the more often must the agent keep the contract. This behaviour by the agent is necessary for the principal's benefit to be non-negative when playing the strategy where contracts are offered.

In the periods when the principal does not offer a contract, the agent will always misuse the resource. The *total probability of misuse* is reduced in the periods when contracts are offered. It is given by

$$(1-a_i)\,(1-\gamma) + \gamma\,(1-a_i) + \gamma\,a_i = 1 - \frac{F}{B}$$

Equation 28

We see that the total probability of misuse is independent of the probability of misuse by elements in the agent country other than the agent. One would perhaps expect the opposite, since the principal also knows the value of γ. The principal can however not observe the frequency of misuse from single-period data, and in the model all periods are assumed identical.

The reduction in the total probability of misuse is F/B compared to the situation without contracts. The reduction is hence increasing in F and falling in B. F is the cost the principal has in making the transfer to the agent, while B is the principal's benefit of a properly managed resource.

The agent balances her misuse of the resource so that the principal's expected payoff is zero, even though the misuse of the resource is reduced when contracts are offered.

5.2.3.3 Comment on the principal's strategy in Equilibrium (1)

Many sets of $\{p_1, p_2, p_3\}$ may satisfy the requirements of Equilibrium (1) / Equation 27. It is not possible to say what set the principal will choose, as the principal has an expected payoff of zero for *all* sets of p_i's satisfying Equation 27.

The demands the principal's strategy must meet in Equilibrium (1) are not very easy to interpret.
The set of partial derivatives $\partial p_i/\partial p_j$ from Equation 27 is given below, with their sign indicated:

$$\frac{\partial p_1}{\partial p_2} = 1 - \frac{L}{T(1-\gamma)} (>0)$$

$$\frac{\partial p_1}{\partial p_3} = \frac{L}{T(1-\gamma)} (>0)$$

$$\frac{\partial p_2}{\partial p_1} = \frac{T(1-\gamma)}{T(1-\gamma)-L} (>0)$$

$$\frac{\partial p_2}{\partial p_3} = -\frac{L}{T(1-\gamma)-L} (<0)$$

$$\frac{\partial p_3}{\partial p_1} = \frac{T(1-\gamma)}{L} (>0)$$

$$\frac{\partial p_3}{\partial p_2} = 1 - \frac{T(1-\gamma)}{L} (<0)$$

When these partial derivatives are investigated, bearing in mind that all p_i's are probabilities, and remembering Equation 27, we find that:

The minimum value for p_1 is

$$\frac{L}{\mu T(1-\gamma)},$$

with $p_2=p_3=0$.

This expression has a value $\in \langle 0,1]$, and hence p_1 is larger than p_2 and p_3 in this case. We would expect p_1 to be larger than p_2 for all combinations of p_i's satisfying Equilibrium (1). The principal should reward the agent higher when she has managed to get state 1 than when she has ended up in state 2.

Should the principal reward the agent higher if state 1 occurred the last period, than if there was no contract (state 3)? If there was no contract the last period, perhaps there has never been any contracts? I expect the principal's strategy to be such that it is not optimal for the agent to break a contract in one period, thinking she with a high probability will get a new contract in the period following the exclusion period. In the appendix, section 7.1.2, I have shown that p_1 always is larger than p_2 in Equilibrium (1) of the basic model, but not necessarily larger than p_3.

Maximum p_1 satisfying Equilibrium (1) is 1, with

$$p_2 \in \left[\frac{\mu T(1-\gamma)-L}{\mu T(1-\gamma)-\mu L}, \frac{\mu T(1-\gamma)-L(1-\mu)}{\mu T(1-\gamma)-\mu L}\right], \text{ and}$$

$p_3 \in [0,1\rangle$[49].

The minimum value for p_3 is 0,

with $p_1 \in \left[\frac{L}{\mu T(1-\gamma)}, 1\right]$, and

$$p_2 \in \left[0, \frac{\mu T(1-\gamma)-L}{\mu T(1-\gamma)-\mu L}\right].$$

The maximum value for $p_3 \in \langle 0,1\rangle$, depending on the relative sizes of μ, γ, T and L.

The minimum value for p_2 is 0, with

$$p_1 \in \left[\frac{L}{\mu T(1-\gamma)}, \frac{L(1+\mu)}{\mu T(1-\gamma)}\right],$$

and $p_3 \in [0,1\rangle$. With $p_2=0$ the agent will never be offered a new contract in the period following possible misuse by the agent.

The maximum value for p_2 is $\frac{\mu T(1-\gamma)-L}{\mu[T(1-\gamma)-L]}$.

[49] The lower limit of p_2 occurs together with the higher limit of p_3, and vice versa.

This value occurs when $p_1=1$ and $p_3=0$.

5.2.3.4 The most forgiving strategy of the principal

The strategy with the maximum value for p_2 can be viewed as the "*most forgiving strategy of the principal*". In this strategy the principal is most willing to offer the agent a new contract even though the agent may have broken the contract in the last period. Since (b) and (c) are valid, $p_2 \in [0,1\rangle$ in the expression above. The most forgiving strategy is given by:

$$\{p_1^*, p_2^*, p_3^*\} = \left\{1, \frac{\mu(1-\gamma)T - L}{\mu[(1-\gamma)T - L]}, 0\right\}$$

Equation 29

Note that a value of zero for p_3 means a permanent breakdown occurs if a contract is not offered in any period. There is a clear trade-off in this strategy. The agent is not very likely to be denied a new contract due to other groups causing misuse, but *if* the principal does not renew a contract after possible misuse by the agent, the agent will never be offered a contract again. $p_3=0$ may also imply a start-up problem.

It is difficult to say how the value of T, L, μ, and γ affect the principal's strategy generally in equilibrium (1).

It is however possible to say something about how the most forgiving strategy depends on these parameters.

By differentiation we find (signs indicated in parenthesis):

$$\frac{\partial p_2^*}{\partial \mu} = \frac{LT(1-\mu)(1-\gamma)}{\mu^2[T(1-\gamma)-L]^2} \quad (>0)$$

Equation 30

$$\frac{\partial p_2^*}{\partial T} = \frac{L(1-\mu)(1-\gamma)}{\mu[T(1-\gamma)-L]^2} \quad (>0)$$

Equation 31

$$\frac{\partial p_2^*}{\partial L} = \frac{-T(1-\mu)(1-\gamma)}{\mu[T(1-\gamma)-L]^2} \quad (<0)$$

Equation 32

$$\frac{\partial p_2^*}{\partial(1-\gamma)} = \frac{LT(1-\mu)}{\mu[T(1-\gamma)-L]^2} \quad (>0)$$

Equation 33

This means that in the most forgiving strategy, the higher the agent values the future (higher μ), the higher will p_2* be. The higher the agent values the future the more important it becomes for her to avoid state 3. Ending up in state 3 means that the agent will never again be offered a contract, with a loss of a valuable future. The principal can hence be fairly sure that the agent will not renege on a contract, and sets p_2* high in response.

The higher the agent values the transfer from the principal (higher T), the higher will the principal set p_2*. When T is large, getting a contract has a high value for the agent, and the principal can be fairly sure that any misuse in state 2 is not due to the agent. Hence the principal can set p_2* high, and will relatively often renew contracts even though misuse occurred in the last period.

The more the agent is forsaking by not using the natural resource in the traditional manner (higher L), the lower will the principal set p_2*. With higher cost of keeping the contract, the lower incentive the agent has to honour the contract, and the more likely is it that any misuse is due to the agent. The principal hence sets p_2* low.

The lower the probability for misuse by the other groups in the agent country (γ) is, the more often will the principal offer a new contract in periods following possible misuse by the agent. When γ has a low value, the principal can be pretty sure that any misuse is due to the agent. When γ is high, it is more uncertain for the principal whether the agent or the other groups in the agent country is responsible for the misuse. The "quality of information" goes down as γ goes up. The principal responds by setting p_2* low to try to make the agent stick to the contract.

Hence, when γ is high, p_2* is low, and as one can see from Equation 26 a_i is high (and vice versa); If the probability of misuse by other groups in the agent country is relatively high, the agent will relatively often keep the contract, and yet the principal will renew a contract relatively seldom after periods of possible misuse. This is opposite the pattern for the other parameters (T, L, μ), where a high a_i leads to a high p_2* (and vice versa). As γ increases the "quality of information"-aspect more than outweighs the incentive to encourage the agent to often keep the contract.

5.3 Model with control-possibilities

5.3.1 The game

This game is similar to the one described in the basic model variant, with the addition that the agent can influence the probability with which other elements in the country cause misuse of the natural resource. For simplicity it is assumed that the control is a discrete "on-off" choice, and further, if it is exerted, it is always effective.

Exerting control has a cost, of a fixed size C, for the agent.

$$C > 0$$

Equation 34

There are assumed no costs associated with having the *possibility* of exerting control. Hence, in any single period where control is not employed, the net benefit to the agent is determined by T and L solely. T is again the benefit to the agent of having the transfer-part of the contract, and L the cost of changing behaviour. It is assumed that (T-L-C)>0.

Let c_i be the agent's state-dependent strategy for exerting control on the other groups, defined in an analogous manner to a_i and p_i. c_i can be viewed as the relative frequency with which the agent exerts control over the other elements in the agent country, reducing their tendency to use the environmental resource. $c_i \in [0,1]$.

The probability with which the other elements cause misuse of the resource is taken to be a step-function dependent of whether control is exerted or not. When control is exerted it is γ^c, and when there is no control it is γ. It is of course assumed that the probability is lower with control than without;

$$\gamma^c < \gamma$$

Equation 35

where both γ^c and γ are $\in \langle 0,1 \rangle$.

Finally, it is assumed that whether the agent exerts control cannot be observed by the principal. If this were not the case, we would effectively have the same situation as in the basic model.

5.3.1.1 States and strategies

Six different combinations of events can be identified in this variant of the model:

Combination 1) Contract was offered, the agent did not exert any control, and no-one in the agent country misused the environmental resource.

Combination 2) Contract was offered, the agent did not exert any control, and only other elements caused misuse of the environmental resource.

Combination 3) No contract was offered. The agent misused the environmental resource, and the agent did not exert any control.

Combination 4) Contract was offered, the agent exerted control, and the natural resource was not misused by any group in the country.

Combination 5) Contract was offered, the agent exerted control, and only other elements in the agent country caused misuse of the environmental resource.

Combination 6) Contract was offered, and the environmental resource was misused by the agent. The agent did not exert any control[50].

As some of these combinations cannot be distinguished by the principal, there are only 3 states in the game. The possible states of the system are combinations 1,2 and 3, indicated by i=1,2,3. Combination (4) is incorporated into state (1), and combinations (5) and (6) are incorporated into state (2).

5.3.1.2 Expected payoffs

The instantaneous payoffs in state (3) are again taken to be a reference value of zero for both players. The symbols used here have the same meaning as in the previous model variant. The present discounted value of the expected payoffs in each state for the principal is denoted G_i.

$$\begin{aligned} G_i &= (1-p_i)\delta G_3 \\ &+ p_i\left\{a_i\begin{bmatrix}(1-c_i)\left[(1-\gamma)(B-F+\delta G_1)+\gamma(-F+\delta G_2)\right] \\ +c_i\left[(1-\gamma^c)(B-F+\delta G_1)+\gamma^c(-F+\delta G_2)\right]\end{bmatrix}+(1-a_i)\left[-F+\delta G_2\right]\right\}\end{aligned}$$

Equation 36

for i=1,2,3.

The present value of the expected payoff for the agent is given by:

[50] When the agent will use the natural resource in the traditional manner, and the principal can not observe the level of misuse, there is no point for the agent to inflict the cost of controlling on herself. If the agent's benefit from the use of the resource was dependent on who/how many exploited it in total, we would have a different situation.

$$H_i = (1-p_i)\mu H_3 + p_i\left\{a_i\left[\begin{array}{l}(1-c_i)\left[(1-\gamma)(T-L+\mu H_1)+\gamma(T-L+\mu H_2)\right]\\ +c_i\left[(1-\gamma^c)(T-L-C+\mu H_1)+\gamma^c(T-L-C+\mu H_2)\right]\end{array}\right] + (1-a_i)\left[T+\mu H_2\right]\right\}$$

Equation 37

for i=1,2,3.

The possible states and payoffs are further illustrated in the game-tree below. The continuation payoffs at the end of each "combination-branch" are in parentheses (P, A).

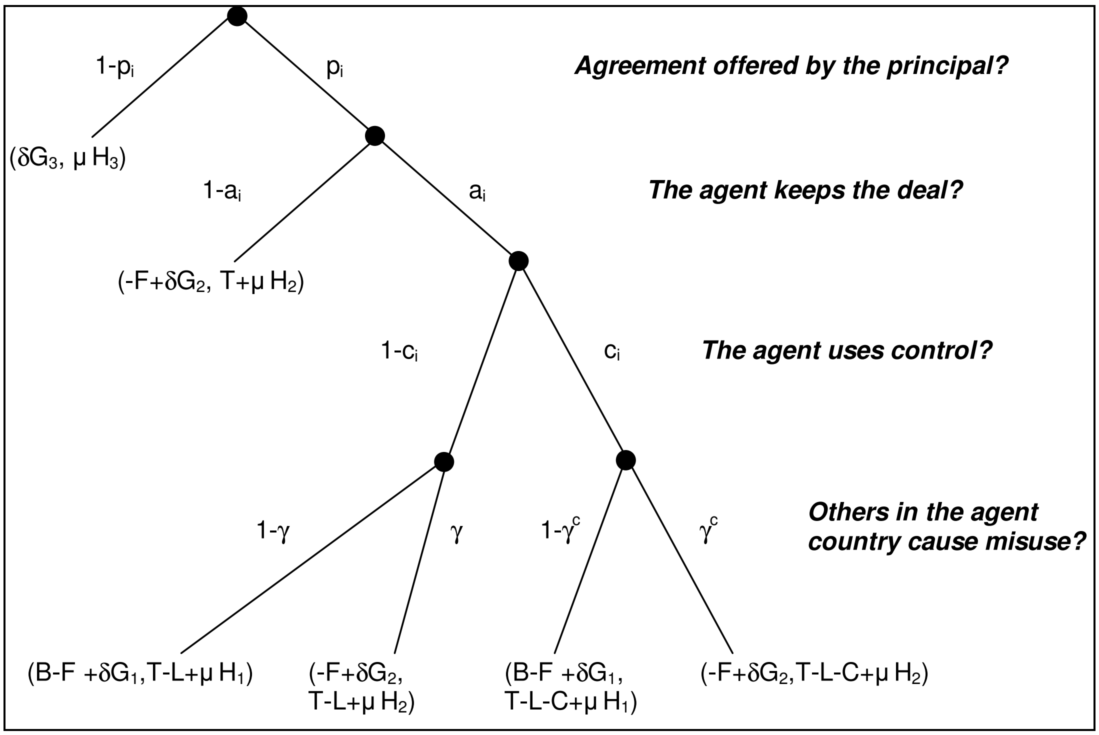

Figure 4 – Game tree excerpt with continuation payoffs (P, A).

5.3.2 Solution to the game

A stationary equilibrium consists of a set of strategies for each state (a_i, c_i, p_i), such that p_i maximises the principal's discounted expected payoff, given a_i, c_i and the current state, while a_i and c_i maximises the agent's discounted expected payoff, given p_i and the current state. The difference from the basic model is that the agent must decide her strategy in two dimensions in each state; Both a_i and c_i must be set. The principal still has only one strategic variable; p_i. The exercise to find the equilibria is left to the appendix, section 7.1.3.

5.3.2.1 Equilibrium (C1):

Given that the following conditions are fulfilled:

a) $$L\frac{(\gamma-\gamma^{c})}{1-\gamma} < C$$

Equation 38

b) $$B \geq \frac{F}{1-\gamma}$$

Equation 39

c) $$T > \frac{L}{1-\gamma}$$

Equation 40

d) $$\mu \geq \frac{L}{T(1-\gamma)}$$

Equation 41

the strategy of the agent is

$$(c_i, a_i) = \left(0, \frac{F}{B(1-\gamma)}\right) \forall i$$

Equation 42

and the strategy of the principal satisfies

$$\mu p_1 T(1-\gamma) - \mu p_2 \left[(1-\gamma)T - L\right] - L(1+\mu p_3) = 0$$

Equation 43

5.3.2.2 Equilibrium (C2)

If the following conditions are fulfilled:

e) $$L\frac{(\gamma-\gamma^{c})}{1-\gamma} > C$$

Equation 44

f) $$B \geq \frac{F}{1-\gamma^c}$$

Equation 45

g) $$T > \frac{L+C}{1-\gamma^c}$$

Equation 46

h) $$\mu \geq \frac{C+L}{T(1-\gamma^c)}$$

Equation 47

the strategy of the agent is

$$(c_i, a_i) = \left(1, \frac{F}{B(1-\gamma^c)}\right) \forall i$$

Equation 48

and the strategy of the principal satisfies

$$\mu p_1 T(1-\gamma^c) - \mu p_2 \left[(1-\gamma^c)T - (C+L)\right] - (C+L)(1+\mu p_3) = 0$$

Equation 49

5.3.2.3 Equilibrium (C3):

If the following conditions are fulfilled:

i) $$L\frac{(\gamma-\gamma^c)}{1-\gamma} = C$$

Equation 50

j) $$B \geq \frac{F}{1-\gamma}$$

Equation 51

k) $$T > \frac{L+C}{1-\gamma^c}$$

Equation 52

l) $\mu \geq \frac{C+L}{T(1-\gamma^c)}$

Equation 53

the strategy of the agent is

$$a_i = \frac{F}{B(1-\gamma + c_i(\gamma - \gamma^c))} \quad \forall i$$

Equation 54

and the strategy of the principal satisfies

$$\mu p_1 T(1-\gamma^c) - \mu p_2 \left[(1-\gamma^c)T - (C+L)\right] - (C+L)(1+\mu p_3) = 0$$

Equation 55

5.3.2.4 Equilibrium (C4):

If the set of conditions in Equilibrium (C1) are not fulfilled, and neither the set of conditions to Equilibrium (C2) or (C3), we get Equilibrium (C4):

p_i=0, c_i=0 and a_i=0 for $\forall$i.

5.3.3 Comments to the control model

The control model presented here can give four different types of equilibria. In Equilibrium (C4) the principal does not offer contracts to the agent, and the agent does not change behaviour. In the other equilibria contracts may be offered at least in some periods, with the agent changing behaviour at least in some periods. In Equilibrium (C1) the agent never exerts control, while in Equilibrium (C2) the agent always employs control if the principal has offered a contract. In Equilibrium (C3) the agent has a mixed strategy in a_i and c_i simultaneously. Just like in the basic model the strategy a_i in equilibrium (C1), (C2) and (C3) is contingent upon a contract being offered in that particular period. For each period where no contract is offered the agent will use the resource in the traditional manner (a_i=0), regardless of which equilibrium the game is in.

Conditions (b) and (f) both state that the expected one-period payoff to the principal, when the agent holds the contract, must be non-negative[51]. If γ is too large for condition (b) to be fulfilled, but condition

[51] There is no need to comment separately on conditions (j-l) of Equilibrium (C3) as they are equivalent to the ones of Equilibrium (C1) and (C2).

(f) is valid, using control is necessary (but not sufficient) to get an equilibrium with contracts offered in some periods. If condition (f) is not valid, neither can (b) be, and we will have Equilibrium (C4).

Conditions (c) and (g) state that the transfer the agent receives in a period with a contract must be larger than the cost of keeping the contract, given that no-one else has misused the resource. If the conditions are not fulfilled the agent will have a negative expected payoff, even when the principal uses the strategy where she is most willing to excuse possible misuse by the agent.

Conditions (d) and (h) say that the agent must have sufficient regard for the future, to value future contracts higher than the benefits given up in this period. In Equilibrium (C2) also the cost of exerting control must be accounted for.

5.3.3.1 The agent's strategy

The rationale for the agent to employ control (under certain conditions) is clear. If they lower the frequency with which the other groups use the resource, they can themselves utilise the resource more often without reducing the chances of being offered contracts in the future. Remember that the principal can not observe who is responsible for misuse. Hence the agent can increase her own benefit compared to the situation without control possibilities.

It is possible that the set of conditions of Equilibrium (C1) are not fulfilled, but that the conditions of Equilibrium (C2) are. In that case, the possibility that the agent can exert control makes contracts possible. The control option can thus make the difference, between status quo with continued misuse, or contracts in some periods giving reduced misuse. If exerting control makes contracts possible there is an obvious (but not here determinable) gain to the agent.

Equilibrium (C1) is basically equivalent to Equilibrium (1) of the basic model. The agent does not employ control as the cost of controlling is larger than the expected benefits that can be taken out. If the agent had used control, the relative reduction in the other groups' propensity to exploit the natural resource would have been

$$\frac{(\gamma-\gamma^{c})}{1-\gamma}.$$

The agent herself could have taken out the one-period benefit (L) from breaking the contract this more often by playing the optimal strategy in a_i. In Equilibrium (C1) this expected increased one-period benefit from controlling is less than the cost of the control.

In Equilibrium (C2) control is employed, due to condition (e) being fulfilled. The control cost is now lower than the expected increase in the one-period benefit from being able to cheat more often in equilibrium. The other conditions and the strategies in this equilibrium are similar to the ones of Equilibrium (C1), with L being replaced by (L+C), and γ^c replacing γ.

It is easily seen that a_i in Equilibrium (C2) is smaller than in Equilibrium (C1), since $\gamma > \gamma^c$ (*ceteris paribus*). As multiple equilibria are possible for the principal the total gain to the agent is indeterminate.

In Equilibrium (C3) the agent is indifferent between exerting control or not, due to condition (j) being valid. In this equilibrium the conditions concerning the agent's discount-factor and the probability with which other groups in the agent country misuse the resource from both Equilibrium (C1) and (C2), must be valid.

The total probability for misuse, in the periods when a contract is offered and the agent does not have the option of exerting control, is in Equation 28 shown to be 1-F/B. The equivalent probability is exactly the same in Equilibrium (C2). The lower probability of misuse by the other groups in the agent country due to the controlling activities, is equalled by increased misuse by the agent.

5.3.3.2 The principal's strategy, including the most forgiving strategy

The principal's strategy in the equilibria with mixed strategies (C1, C2 and C3) have the same relationship between the p_i's and the different parameters as the basic model (with (C+L) replacing L and γ^c replacing γ for Equilibrium (C2)). Interpretations are equally difficult.

In section 5.2.3.4 I defined the most forgiving strategy of the principal as the strategy where the principal is most willing to offer the agent a new contract even though the agent may have broken the contract in the last period.

The most forgiving strategy in Equilibrium (C1) is the same as in Equilibrium (1) of the basic model:

$$\{p_1^*, p_2^*, p_3^*\} = \left\{1, \frac{\mu(1-\gamma)T - L}{\mu[(1-\gamma)T - L]}, 0\right\}$$

Equation 56

The most forgiving strategy of the principal in Equilibrium (C2) is

$$\{p_1^*, p_2^*, p_3^*\} = \left\{1, \frac{\mu(1-\gamma^c)T - (C+L)}{\mu[(1-\gamma^c)T - (C+L)]}, 0\right\}$$

Equation 57

Equilibrium (C1) and (C2) are mutually excluding, due to the nature of conditions (a) and (e). When one set of conditions is valid, and not the other, this can be because all the variables have different values. To try to compare the most forgiving strategy in the two equilibria I will assume that all parameters except the control cost C are fixed. T, L and μ hence have the same value in both equilibria, but $\gamma > \gamma^c$ of course.

Assume that C is very small, and that the conditions of Equilibrium (C2) are valid. As C increases one eventually comes to a point where condition (e) (Equation 44) of Equilibrium (C2) is no longer valid, but instead condition (i) (Equation 50) of Equilibrium (C3), and then condition (a) (Equation 38) of Equilibrium (C1).

Examining p_2^* from Equation 57 we find that

$$\frac{\partial p_2^*}{\partial C} = \frac{(\mu - 1)T(1-\gamma^c)}{\mu[T(1-\gamma^c) - (C+L)]^2} \quad (<0).$$

Equation 58

p_2^* in Equilibrium (C2) is monotonically decreasing in control cost C. We want to find out what value p_2^* approaches as the control cost approaches the value where condition (a) becomes valid (and the agent will stop using control). It is easily verified that in Equilibrium (C2)

$$\lim_{C \to \frac{L(\gamma-\gamma^c)}{(1-\gamma)}} p_2^* = \frac{\mu(1-\gamma)T - L}{\mu[(1-\gamma)T - L]}$$

Equation 59

This is the value of p_2^* in Equilibrium (C1). It is independent of C.

When C is very low, the principal is relatively likely to renew a contract after a period of possible misuse by the agent. As C increases the principal gets less likely to renew a contract following possible misuse by the agent. When C is so large that the players switch from Equilibrium (C2) to (C1), the value of p_2^* from Equilibrium (C2) has got so low that it is equal to the p_2^*-value of Equilibrium (C1). Graphically it can be illustrated like below.

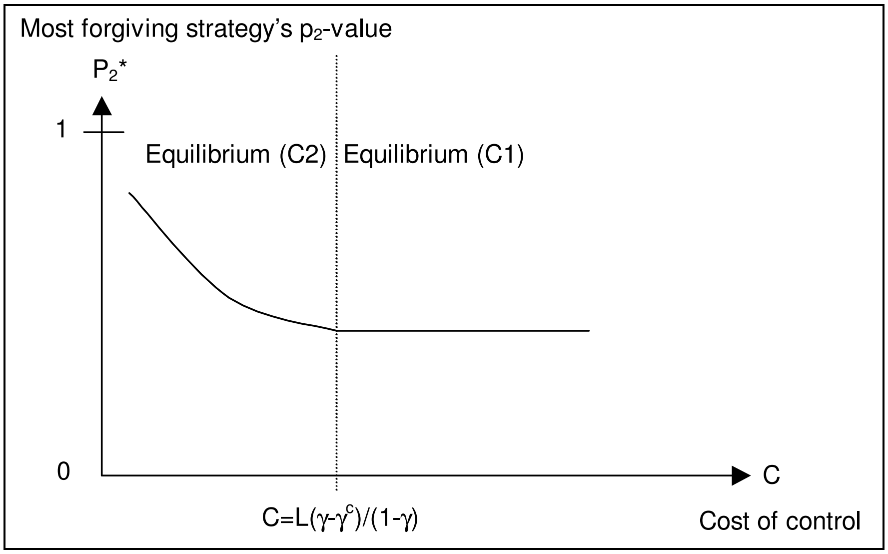

Figure 5 – The most forgiving strategy's dependence on the agent's control costs

If the cost of controlling is low, it probably pays for the agent to exert control. However, it only makes sense for the agent to exert control if she will *not* misuse the resource. When C is low, it is more likely that misuse is due to other elements in the agent country, than the agent herself, than when C is high. The principal responds to this fact by setting p_2* as in Figure 5. In Equilibrium (C1) the agent will not exert control anyway, and p_2* is then independent of the value of C.

5.4 The models and the Kyoto mechanisms

Here I have presented models of repeated principal-agent relationships with uncertainty and private information on the agent's part. Joint implementation contracts can have a similar setting. A host may have private information on:

- whether the investment actually is made, or if it is carried out in the manner agreed;
- whether she is performing the right actions after the investment is made (it might be costly to operate new equipment or in accordance with emissions-reducing routines);
- whether the investment is countered elsewhere (perhaps due to the money from the JI-project the host liberates funding for expansion elsewhere, leading to more emissions, or a tree-planting project is countered with agricultural conversion of forests elsewhere in the country).

There may be many uncertain elements related to JI-projects that the host could utilise when hiding own breaching of a contract, for example:

- there may be uncertainties with the estimated cost of a project, leading to the final investment being less in terms of actions or equipment, but unchanged in terms of cost;

- uncertainties with monitoring of effects;
- carbon sink enhancement projects may have their emissions reducing effects altered by others/nature;
- whether under-contractors cheat.

I also expect that JI project-investors will try to have several projects with the same host, as this reduces the average transaction costs for the projects. I have assumed identical projects in each period. Although this is a simplifying assumption, it could be possible with several similar JI-projects following each other (e.g. upgrading of a number of similar fossil fuel power plants, all belonging to the same JI project-host).

Joint implementation relationships fits well with principal-agent relationship of the economics literature. In my models the principal's tool for affecting the agent's actions is the frequency with which she offer the agent contracts in future periods. If a contract is offered the agent always accepts, receives a transfer, and then decides whether to act in accordance with the principal's wish this period, or to cheat. If the agent cheats, the principal will not get a benefit from the contract. Independent of the agent's actions a stochastic element can make it seem as if the agent has not kept the contract/give the principal no benefit from the contract. Both agent and principal know about this stochastic element. In the second variant of the model the agent can influence the probability with which the stochastic element causes what the principal observes as misuse. The principal can not observe the actions of the agent nor the stochastic element.

I will comment on the different equilibria, conditions and strategies of the models in relation to JI-contracts, starting with the basic model. There are two types of equilibria in the basic model. One is in pure strategies, and contracts are never offered. The other type of equilibrium is in mixed strategies, and contracts may be offered some periods. Multiple equilibria exist within this latter type of equilibrium. A sequence of periods with and without contracts is possible in the latter type, and the sequence is decided endogenously in the model. The agent (host in a JI project) will use her private information to increase own payoff in the periods when contracts are offered (and hence overall), while the principal's payoff is constant.

The conditions necessary to have contracts possible at least in some periods will now be discussed in relation to JI-contracts (See Equilibrium (1) of the basic model).

The investor's expected benefit from offering a one-period contract, given that the host sticks to the contract must be non-negative. The investor's gain of having the investment performed successfully must be larger than the cost of the necessary transfer to make the agent perform the investment, by a factor depending on the probability with which the stochastic element causes misuse of the resource. With increasing probability, the difference between these two must also increase, for the equilibrium to be possible. If the probability is too high in comparison to the difference between the investor's gain and cost the potential host will not be offered a contract.

Also the potential host's expected one-period compensation must be large enough, compared to the cost of making the investment and the probability of the stochastic element eliminating the investor's gain of the investment. The probability must also be so low that the investor knows the host will not always cheat. As the probability of other elements causing misuse goes up, the host's chances of cheating goes up, since it becomes easier to "hide" behind the effect of the stochastic element. Remember that the investor also knows about the stochastic element.

The third condition states that the host must have sufficient regard for the future to value the gains of future contracts more than this period's benefit of breaching the contract.

The host's strategy in Equilibrium (1) is such that the higher the cost is for the investor, or the less the investor values the effect of a successful investment, the more often must the host keep the contract to stay in the equilibrium. Also, the higher the stochastic element's probability of destroying the investor's benefit from the investment is, the more often must the host stick to the contract.

Assume we have a JI-project planting trees as a carbon sink enhancement, and the stochastic element is the probability of forest-fires and farmers illegally burning forests for agricultural conversion. The higher this (sum) probability is, the more often must the project host plant trees to stay within the equilibrium and be eligible for valuable contracts in future periods. If the probability is too high there will be no projects offered. If the host values the future too little compared to the one-period gains, there will be no contracts.

The investor's strategy in Equilibrium (1) is not very easy to interpret.

The harshest or least forgiving strategy is to offer a new JI-contract only after an investment has been successful, and then with a frequency equal to or less than 1. If the investor in a period gets no benefit from making the transfer, either due to the agent's actions or the stochastic element, the investor will not offer a new contract, and following a period without a contract the investor never offers a contract. In practice this means the relationship is ended.

In the strategy where the investor is most forgiving – i.e. most willing too accept that the cause of misuse might be the stochastic element and hence offer a new contract – the investor always renews a contract that has given a benefit to her. The investor will renew a seemingly broken contract most often, but will never offer a contract if there were no contract last period. In this strategy there is a clear trade off for the host, between getting a new contract after periods of possible breach and getting a permanent breakdown of the JI-relationship.

The investor's strategy in Equilibrium (1) may also be such that contracts are offered with a positive probability if there was a contract last period that gave her a benefit or if there was no contract last period, but not if a contract last period gave no benefit.

We see that several types of behaviour by the investor can be explained as an equilibrium in this model, with several different sequences of contracts offered and not.

The model with control possibilities has 4 possible equilibria. One is that contracts are never offered. There are 3 equilibria in mixed strategies. In all these 3 equilibria the host has a mixed strategy on cheating/sticking to the contract. The difference is that the host either never employs control, always employs control, or has a mixed strategy in control as well.

The conditions that must be fulfilled to get the mixed equilibria are mostly very similar between the basic model and the model with control possibilities. The big difference is in the host's strategy due to the ability to exert some control over the stochastic element. This is modelled as a step function, lowering the probability of the stochastic element destroying the investor's benefit from the JI-investment. Exerting control is assumed to have a fixed cost for the host, while it is costless to have the *option* of exerting control.

In the equilibrium where control is or might be employed, it is possible that the host breaches the contract more often. That way she can save the cost of making the investment and get a higher net gain. The condition is that the cost of controlling is sufficiently low compared to the extra one-period benefit she can take out.

It is possible that exerting control reduces the probability, with which the stochastic element destroys the investor's gains from the investment, enough to *facilitate* an equilibrium where contracts can be offered. The option of control can hence be the difference between JI-contracts in some periods, or not at all.

The total probability of misuse is independent of whether the host employs control or not. If the host employs control to reduce the stochastic elements' probability of apparent contract-breach, she exactly equals out this reduction with higher frequency of breaching herself. The host uses her private information to get a higher net gain, on the expense of the investor.

I will now briefly argue that my models *might* also be able to say something about international emissions trading under the Kyoto Protocol. This will depend on the rules for the IET. It is possible that two quota holders enter a relationship with the aim of selling/buying a quota for several consecutive years. IET-contracts could be for several consecutive periods (for example for several sub-periods within a longer commitment period), according to Hagem (1996)[52]. It is possible that a quota seller will not match the sale with emission reducing measures, which means the overall level of greenhouse gases will be higher than if IET was not possible (Holtsmark and Hagem 1998). The quota seller might hide behind asymmetric information and possible other sources of failure to fulfil the contract, similar to what I have described for JI-relationships. If *countries* trade quotas and the quota/emission reduction is delegated down to national industries/actors, I expect the possibilities for cheating to be the highest. With more actors the feasibility of control in general goes down. The model with control possibilities could describe that situation quite well. If it can be verified that a quota sale has not been matched with the contracted abatement efforts or carbon sink enhancement, the seller's chances of trading quotas in the future might be affected, depending on how buyers view the seller's "guilt" in these cases.

5.5 Summary

In this chapter I have developed two fairly simple models which describe repeated principal-agent relationships. The principal tries to influence the agent's behaviour affecting a natural resource, in a period of time, by offering compensation to the agent. The agent always accepts and immediately receives the compensation, but may not always change her behaviour. The principal's carrot or stick is that she may or may not offer a contract in the next period, depending on the observed state of the natural resource. Stochastic elements in the agent country may also influence the state of the resource so that the principal regards it as misused. The principal can not observe the agent's actions or whether misuse is caused by stochastic elements, but only the state of the resource.

There are two basic types of possible equilibria in the models:

1. One in which contracts are never offered;
2. One where contracts are possible at least in some periods.

For a potential agent to be offered contracts certain criteria must be met. The probability of misuse by others than the agent must not be too high, and the agent must have sufficient regard for the future, in relation to the costs and benefits the agent and principal can have with a contract. Even if the criteria are fulfilled, an agent can not expect to be offered contracts in every period, as long as there is a positive probability for other elements causing misuse of the resource. After periods without contracts the agent may again be offered a contract, depending on the principal's strategy. The sequence of periods with and without contracts is determined endogenously in the model, based on the players' strategy decisions.

[52] Remember that the Kyoto Protocol specifies the target as the average emission levels over each year between 2008-2012.

The models show how different basic variables affect the chances of contracts being struck and the players' strategies in the equilibria.

For the periods when contracts are made it can be noted that (in equilibrium, *ceteris paribus*):

- The costlier it is for the principal to make the transfer to the agent, the more often will the agent manage the resource according to the principal's wishes.
- The higher the principal values that the natural resource be unspoilt, the more often will the agent misuse the resource when contracts are made.
- The higher probability there is for misuse of the resource by others than the agent, the more often will the agent keep the contract.

The total probability of misuse is lower in the periods when contracts are made, and the agent has a higher payoff, than when contracts are not offered. The agent's overall expected payoff is higher in the equilibria where contracts are possible than when they are not. The expected payoff to the principal is however equal in all equilibria. In the equilibria where contracts are possible, the agent sets her strategy so that the principal is indifferent between never offering contracts, or offering contracts in some specific periods. The agent utilises her private information to increase own benefit at the expense of the principal.

In the control model, where the agent can influence the probability with which other elements misuse the resource, the total probability of misuse is independent of whether control is exercised or not, as long as a contract is offered. This is due to the agent's strategy, where she breaks the contract more often when control is used, to the point where total probability of misuse is unchanged. By cheating the agent gets a bigger payoff. The choice of whether to use control or not, depends on the cost of control compared to the size of the possible gain the agent can take out due to a reduced probability of misuse by others.

The possibility of exerting control can reduce the probability of misuse by other groups below the threshold where contracts may be offered by the principal. Hence the option of control can facilitate contracts. This is an important conclusion.

Many different strategies by the principal can satisfy the requirements for equilibria with contracts possible. It is not possible to say which of the strategies the principal will choose. By the same reason it is difficult to make general comments on the principal's strategy.

I have defined "the principal's most forgiving strategy" as the strategy where the agent has the largest probability of being offered a new contract following a period with possible misuse by her (as observed by the principal). The principal will in this strategy always renew a contract if no misuse has occurred. However, if there were no contract in the last period, the principal will never offer one either. The trade off in this strategy is that if the agent has a large chance of a new contract after a period of possible misuse, she may at some point be forever excluded from future contracts.

In this most forgiving strategy of the principal, the following can be stated about the principal's propensity to renew a contract after a period of possible misuse by the agent (in equilibrium):

- The higher the agent values the transfer from the principal, the more often will the principal offer a new contract;
- The higher benefit the agent has from using the natural resource in the traditional manner, the less often will the principal offer a new contract;
- The higher regard the agent has for the future, the more often will the principal offer a new contract;
- In the equilibrium where the agent will use control, the principal will renew a possibly broken contract more often the cheaper it is for the agent to control.

I think the models may suitably describe and explain some types of joint implementation relationships, and maybe also some cases of international emissions trading. Both these mechanisms are allowed under the Kyoto Protocol to lower the cost of reducing greenhouse gas levels. High transaction costs are mentioned as one of the major obstacles to JI-projects. I have assumed repeated relationships between host and investor, as a way to lower these costs. For JI-projects with the host in a developing or EIT country, I believe the chances of *hidden action*-problems to be larger than if the host is in a developed country. This will be due to general economic and political instability, including corruption. I also expect that many hosts in developing countries need to receive the transfer from the investor at the start of the project, in part or in full. The transfer will be necessary to free the host from her financial constraints, and make her able to perform the project. All these aspects are included in my models. The model with control possibilities describes the situation where a host can influence to what extent (probability) other factors make it look as if she has breached the contract. That the transfer is made before the project has really started takes away the traditionally most powerful tool for a principal to influence an agent's actions – the possibility of withholding payment in case of breach of contract.

With the assumptions above, JI-contracts may be offered to the host at least in some periods, given that certain conditions are met. The conditions concerns the relationships between costs and benefits for the host and investor and the probability of other elements in the host country causing misuse/apparent breach of contract. As the investor's "carrot" to make the host fulfil the contract is the possibility of future contracts, it is required that the host values the future sufficiently. The strategies the host and investor employs, in the equilibrium where contracts may be offered, are such that a sequence of periods with and without contracts are possible, and determined endogenously in the model. The host's strategy is so that the principal gets no net gain from offering the contracts. If the chances of others causing misuse is relatively high the agent relatively often sticks to the contract, and vice versa. The private information the host holds provides her with the opportunity to get a benefit at the investor's expense.

Several different strategies by the investor are possible in the equilibria where contracts may be offered. The strategies can range from quite "forgiving ", where possible contract breach is nearly always excused due to the presence of uncertainty, to "harsh" ones, where possible contract breach is never excused. In the most forgiving strategy the investor will always offer a new contract if the contract was fulfilled, nearly always if there was a breach, but never if there was no contract the last period. The high probability of being excused is paired with the low probability of being barred from new contracts forever. The trade-off is quite clear.

The harshest strategy of the investor involves that possible contract breach is never honoured with a new contract the next period, but also that fulfilling the contract will not guarantee a new contract. The chances of being offered a contract after a period without one may however be present. Loosely, it might be interpreted as a investor who switches from co-operation with one potential host to another, although this is not possible within the framework of the models here. Switching in reality would mean higher transaction costs. An extension of the model, where switching between hosts are possible and transaction costs are included, could be interesting, if possible.

An obvious weakness with the models is that the parameters influencing whether a contract will be offered, and also the strategies of the actors, are taken as fixed. In real life they will differ from period to period. The changes can be dependent of what actions the players take, but also the opposite is likely. It is not likely that all JI-contracts are identical. The agent might also affect the principal's valuation of the environmental resource being managed in a specific manner. Advances in the technologies to monitor and control misuse of the resource will most likely increase efficiency and reduce the costs of controlling. Further, the principal will in practically all cases be able to observe, at least to some extent, the actions of the agent and the other elements in the agent country influencing the resource. An extension of the model to account for the things mentioned above, will however make the solving of the models very complex, if possible at all.

The models I have developed are rather simple, but they are able to point at conditions that must be met to get JI (or IET contracts) in a specific setting, specifically where the agent is in a "Economy in transition" or developing country. High transaction costs are seen as a major obstacle to JI-contracts. I assume JI-relationships where host and investor perform several similar projects will have relatively low transaction costs per projects. Several authors have pointed out the need to include projects in the developing and EIT countries to reduce greenhouse-gases, to lower overall cost of combating global warming. I believe this poses two specific challenges; JI-hosts will need to receive the transfer from the host before the project is performed, and the chances of contract breach by the host will be relatively high.

My conclusion, based on my models, is that JI-contracts between a host and investor can be possible under the assumptions above. The models point at how different factors affect the players' behaviour in such a setting. The models can explain (or describe) different sequences of behaviour by investors and hosts of repeated JI and IET contracts, all within one type of equilibrium. Reducing the probability of external factors causing project failure can facilitate JI-contracts in some cases. The option of control can be the difference between having contracts in some periods, or not at all. A JI project-investor should try to reduce the level of private information on the host's part, to avoid own benefit being reduced due to contract breach by the host.

6. SUMMARY AND CONCLUSIONS

In this thesis I have taken a broad view on international environmental co-operation; What are the incentives, obstacles and ways to enhance participation and compliance with international environmental agreements. I have also looked at a more specific issue; The implementation of the "flexible mechanisms" of the Kyoto Protocol, and particularly joint implementation projects between an investor in a developed country and a host in an economy in transition or developing country.

Many IEAs exist today. Dominant features of them are that they have limited participation and they are only a step on the way to optimality. A usual problem with international externalities is that countries only get a fraction of the benefit from their own (costly) efforts to deal with the externality. Co-operation by all stakeholders will however lead to the highest total net benefit. This should be a strong incentive for co-operation. The distribution of costs and benefits between the co-operators are however rarely even, and side-transfers are often required to get participation by all. (Carraro and Siniscalco 1995).

Before an IEA is reached countries must agree that a problem exists and needs to be given priority. In addition, and often more difficult, the sharing of responsibility and costs must be agreed upon. (Blackhurst and Subramanian 1992). It must be profitable to join agreements, and free-riding must be deterred (Carraro 1997a).

The simple game of the Prisoners' Dilemma helps us to analyse situations where the temptation to free-ride on others' efforts exists. This temptation depends on the gains of such behaviour, the chance of being discovered, and the potential punishment. International co-operation is often modelled as repeated games, and several types of strategies can sustain co-operation in this framework. "Defection" in the theory of repeated games does not distinguish between free-riding and non-compliance (Barrett 1999).

Barrett's (1994) and others' concept of self-enforcing IEAs is based upon the common situation that as the number of co-operating countries increase, the benefit of free-riding increases faster than the individual benefit of co-operating. Then, at some point the individual benefit of free-riding will be larger than of co-operation. This is in spite of the total sum benefit being the largest with co-operation by all. For almost all the cases investigated by Barrett (1994) and Carraro and Siniscalco (1993) the size of the self-enforced coalition is relatively small. A self-enforced agreement must fulfil both individual and collective rationality (Barrett 1999). It must be profitable for individual countries to join and fulfil the obligations of the agreement. At the same time it must be rational to punish a deviator, rather than for the remaining countries to renegotiate the agreement. A collectively rational agreement will have credible threats of punishment. Barrett (1999) shows that self-enforced full co-operation can only be sustained if the gains of co-operation are small; When co-operation is not really needed.

The sum total benefit with co-operation by all is normally larger than with the self-enforced coalition, and Carraro and Siniscalco (1993) propose to use the self-enforced coalition as a nucleus to expand co-operation by the aid of self-financed side transfers. Barrett (1994) is pessimistic concerning such use of side transfers, as that agreement would again not be self-enforcing.

Chander and Tulkens (1995) have the opposite view of Barrett: Side transfers are the key to achieve participation by all. They present a formula for cost-sharing in an IEA where all will be better off than with the Nash non-co-operative outcome. Chander and Tulkens' (1995) proposed IEA should be presented to all, and if some countries would want to form a free-riding coalition, hoping for a higher benefit, the threat of the remaining countries playing Nash against the coalition would be sufficient to deter them from that.

The two opposing views held by Barrett (1994) and Chander and Tulkens (1995) differ principally on how an IEA comes about, and to what extent free-riding can be avoided. In the limit, do countries join one by one until the self-enforced agreement is a fact, or does one negotiate IEAs that require participation by all to come into effect? If, in an ideal situation with all countries co-operating, a country decided to try to free-ride, would the remaining co-operators accept it, and just adjust their actions, or would they actively try to punish the free-rider? Barrett (1998) thinks that the punishment proposed by Chander and Tulkens (1995) does not constitute a credible threat.

In reality IEAs concerning externalities between many countries are negotiated by a large number of countries, and they come into effect when a certain fraction of the countries have ratified it. Compared to the size of the self-enforced coalitions calculated by Barrett (1994) and Carraro and Siniscalco (1995) the required fractions seem large. Yet, most of the IEAs that have been negotiated through come into effect. A minimum participation clause provides incentives for countries to join, as they then are sure not to have to perform measures unilaterally (Barrett 1998). However, for IEAs with static targets for its parties (independent of the number and/or size of other parties), they do not provide incentive for successive accession beyond the marginal ratification level (Barrett 1998b). The Kyoto Protocol has such static targets. A relatively small number of large/important countries are responsible for the major part of many different global/international environmental problems. Hence measures by these countries can solve most of the problem in question. Once these major players have joined the IEA the gains of free-riding are small compared to the benefits of being part of the "good company" (Blackhurst and Subramanian 1992).

That states may have moral obligations, also in their own view, have been pointed out by several authors, including Barrett (1990, 1994), Blackhurst and Subramanian (1992) and Hoel (1994). If countries commit themselves to co-operation, a self-enforcing coalition can be expanded by bribing other countries to join (Carraro and Siniscalco 1995). Another way to expand international co-operation on public environmental goods is to link it with co-operation in a field where non-participants can be excluded from getting benefits. Both Carraro and Siniscalco (1997) and Katsoulacos (1997) show that issue-linking can be very effective in stabilising IEAs.

Incorporating trade provisions into IEAs can be an effective way to deter free-riding. Barrett (1997a) finds that full co-operation in an IEA can be sustained through the credible threat of a trade sanction for a large range of realistic parameter values. In equilibrium trade is not actually restricted, as the threat itself is enough. When a limited number of countries have agreed to introduce domestic measures to deal with a global externality (or at least one affecting also countries outside this group), efficiency will not be obtained unless the countries supplement their domestic environmental measures with trade regulations (Mæstad 1998).

Compliance of IEAs is usually costly, and one expects countries to cheat if they can get away with it (Barrett 1994, Russell 1996). IEAs should have good procedures for dealing with non-compliance. If the procedures are not good enough there, and the conflict involves other aspects of international relations, the parties might revert will use other international agreements dispute-resolving mechanisms. If trade is involved the World Trade Organisation and the non-compliance mechanisms under GATT can be used. The environment will then not be the winner (Werksman, lecture 15.05.98).

Several authors however conclude that compliance is the norm (Enders and Porges 1992, Chayes and Chayes 1995, Werksmann 1996). Barrett (1998b) says non-compliance is “extremely rare”. Sovereignty of states mean they are free to choose which agreements to enter. Barrett (1999) concludes that free-riding is the constraint on international co-operation, and not compliance enforcement. Downs et al (1996)[53] and Enders and Porges (1992) ask if “deep co-operation” can be agreed and sustained; “Compliance can be expected as an agreed IEA only reflects the costs and benefits of the underlying non co-operative game”. If countries do not comply it is because they are not able (Werksman lecture 15.05.98). Assistance, perhaps in combination with coercive measures, should hence be the remedy (Werksman lecture 15.05.98, Barrett 1998b).

The Kyoto Protocol obligations will cost the Annex I countries a significant fraction of their GDP, and hence can not be said to be “shallow” (Barrett 1998b). The Kyoto Protocol has no provisions to ensure

[53] Downs, GW, M Rocke and PN Barsoom 1996: “Is the good news about compliance good news about co-operation?”, *International Organization*, 50, 379-406. Quoted in Barrett 1998b.

compliance, and have not entered into force yet, so we can't choose between the two explanations (Barrett 1998b).

The Montreal Protocol has built-in incentives for participation. This works as free rider deterrence (Barrett 1998b). Barrett (1998) state that once free-riding can be deterred, compliance comes for free. If countries will not comply they are also barred from the positive incentive to participation. “A carrot withheld is stick”, as Werksman (lecture 15.05.98) puts it. Barrett (1998b) considers it as a potentially large shortcoming of the Kyoto Protocol that it contains no incentives for countries to join it, apart from the potential gain of international co-operation. As we have seen, the potential gain of co-operation is not enough to avoid free-riding. Barrett (1998b) asks if similar trade sanction provisions like the Montreal Protocol's could be included in the Kyoto Protocol; As greenhouse gas emissions are influenced by the production of any good, a complete trade sanction would not be credible. The option of trade sanctions in a limited range of products could perhaps be possible, Barrett (1998b) suggests. As far as he knows the subject never came up in Kyoto.

Overall efficient IEAs have not yet been possible, both due to technical and political limitations (Hagem 1996). For cost-efficient implementation of IEAs the marginal cost of the last measure performed in each country must be equal (Chander et al 1999). This marginal cost must also not be larger than the marginal benefit. The Kyoto Protocol opens up for “flexible mechanisms” to achieve cost-efficiency. These are international emissions trading (IET), joint implementation (JI) and the Clean Development Mechanism (CDM). The detailed rules to govern their use have not yet been decided. It may happen at COP-6 in November 2000.

The Kyoto-mechanisms can give cost-efficient implementation of the protocol's targets, but there are several factors that can reduce their potential, or even lead to lower efficiency than if the mechanisms were not allowed.

Hagem (1996) and Holtsmark and Hagem (1996) investigate how actors with market power can influence the price of quotas, or use tradable quotas as an instrument of monopolisation. As market power can be influenced by the allocation of quotas, the issue of burden-sharing and efficiency are not separable. Large transactions costs may well be an obstacle to cost-efficiency, but probably only in the establishing phase of an IET-regime (Holtsmark and Hagem 1996).

The parties to a contract under the Kyoto mechanisms will be under different jurisdictions, and Janssen (1999) would like the contract to be self-enforcing. He investigates the role of national authorities, and the possibility of strategic delegation. Both can lead to the parties being credibly committed to co-operation.

Private information can be used by parties for their own benefit, at the expense of the other party and global cost-efficiency (Torvanger et al 1994, Hagem 1996). Torvanger et al (1994) and Hagem

(1996b) model a situation where a potential host of a JI-project abstains from investments today, hoping to have them financed with a profit in the future. This can lead to higher overall emissions than if JI was not allowed. Hagem (1996c) look at the situation where the host does not know her true cost of implementing a JI-project of several sub-projects, until some of these sub-projects have been performed. The host may then consider breaching the contract if costs are higher than expected. Hagem (1996c) look at contract design and the value of information/monitoring for the investor of the project, both before and after the contract is made.

Authors agree that emission limits must be set for the non-Annex I countries in the future (Barrett 1998b, Chander et al 1999, Helms 1999). This is to lower the overall cost of greenhouse gas mitigation. It is important for efficiency because the cheapest emissions-reducing projects are in the developing and EIT countries. It is also important as the transaction costs of JI-projects will be high due to asymmetric information and uncertainty without emission baselines for these countries. Barrett (1998b) underlines that the developing countries need not pay themselves to achieve the reductions, but it is important that limits are set and reductions take place there. The wish to reduce the amount of flexibility in the implementation of Annex B countries' obligations is seen as harming the environment by Barrett (1998b), since it will raise overall costs of reducing greenhouse-gas levels. The cost of implementation must surely matter when countries consider ratifying the Kyoto Protocol.

Efforts to reduce emissions, in countries with obligations under the Kyoto protocol or in specific sectors/firms in countries without obligations, may increase the total emissions from countries without obligations. *Leakages* may reduce the overall effect of the JI-projects (Hagem 1996). If most emissions reductions can be obtained through cheap JI-projects using old technology, there is a fear too little technological development will take place. This might have a negative long-run effect on global emissions (Holtsmark and Hagem 1998).

To limit the "hot-air" trading with the Economies in transition has been put forward as an important issue by several authors (Barrett 1998b, Torvanger 1998). As emissions-reductions below the target in this commitment period is allowed banked into the next commitment period, one might ask where the core of concern lies. Whether paper trades will take place now between Annex II countries and the Economies in transition, or between now and the future in the Economies in transition might be unimportant. It is possible that it can affect the targets to be negotiated for the next period, but I think this could affect both Annex II countries and the EITs, and hence the overall effect could go either way.

The flexible mechanisms in the Kyoto Protocol can potentially reduce the cost to reduce greenhouse gas levels substantially (Barrett 1998, St.meld nr. 29), but there are several obstacles in the way. In chapter 5 I develop two models to investigate a joint implementation relationship between an investor and a host, that I believe can be appropriate, especially if the host is in a developing country or one of the Economies in transition. High transaction costs are expected to be a major obstacle in establishing

JI-contracts (Bohm 1994, Barrett 1998b). I believe they will be reduced by potential JI-investors concentrating on a few potential project-host, and rather performing several projects with each. I have modelled this as an infinitely repeated principal-agent relationship. Hosts to joint implementation projects in developing or EIT countries likely face severe financial constraints. Hence they will need some or all of the transfer from the investor before the project is completed. I have modelled this as if the transfers are made before the project starts. This means taking away the traditionally most powerful tool in principal-agent models that a principal has to influence an agent's actions - the ability to withhold the compensation. Developing and EIT countries in general have a higher degree of political and economical instability, as well as corruption and crime, compared to the developed countries. I believe this increases the chances of cheating on the part of the project host. I have assumed in my modelling that there are uncertain factors that can cause project failure, and the actions of the host and uncertain factors can not be observed by the investor. The investor can only influence the host's propensity to fulfil the contract by how often she offers the host a new contract. These starting points are identical for the two models. In the second model the host can reduce the probability of external factors causing project failure, but at a cost.

I find that joint implementation contracts are possible under these assumptions, under certain conditions. The probability of external factors causing misuse must not be too large, and the host must value the future sufficiently. This is in relation to the investor and host's expected costs and benefits of the project. Even if contracts may be offered to the host, she will likely not be offered contracts every period. A sequence of periods with and without contracts can occur, and the sequence is decided endogenously in the model.

Numerous strategies by the investor are possible in the equilibria where contracts are offered. They range from where the investor is very willing to offer a new contract after possible breach by the host, to newer offering a new contract after possible breach. Hence the models allow and describe a fairly wide range of behaviour by an investor offering JI-contracts. The investor's possible strategies have a trade-off between excusing possible breach and offering contracts after periods without contracts.

Apart from the finding that JI-contracts are possible under the assumptions I have set, major conclusions are that

- to facilitate JI-contracts under the assumptions of my models potential hosts and investors should try to reduce the probability with which external factors cause project failure
- a JI-project investor should try to reduce the level of asymmetric information with the host to avoid own benefit being eliminated by contract breach by the host.

The Kyoto Protocol needs to reach its targets cost-efficiently for major industrial countries to ratify it. Emissions trading and joint implementation among the Annex I countries will help to achieve this, even though several problems must be overcome. It is also required that measures are implemented in the developing countries. The Clean Development Mechanism opens up for this, but there are dangers of adverse selection of projects, paper trades and leakages. The majority of non-Annex B countries are not willing to accept emission limitations at present. The opportunity to engage in CDM-projects, make a benefit on the trade and get access to new technology have already tempted some into announcing voluntarily commitments. Even if these commitments do not constitute anything but business-as-usual targets, they will lower the transaction costs of CDM-projects considerably. Then it will also be easier for the Annex B countries to accept paying for measures in the developing countries. Involving non-Annex B countries is necessary to lower the total bill of greenhouse gas reductions, not so much to share costs between industrialised and developing countries. We have seen that joint implementation with hosts in developing countries and economies in transition are possible, but that the rules to govern the Kyoto mechanisms must be set carefully. Hopefully the COP-6 in The Hague in November 2000 will manage to agree on a set of rules that will overcome most of the problems discussed here.

6.1 Conclusions

In this thesis we have seen that full co-operation in dealing with international environmental externalities will give the highest sum benefit for the countries involved, but that countries have the incentive to increase their individual benefit by free-riding on the virtuous behaviour of others. As there is no supra-national authority to enforce compliance, this can make co-operation break down or keep it from being established.

To enhance co-operation it must be made beneficial for each individual country to join an IEA, and free-riding and non-compliance should be deterred. We have seen that several mechanisms can promote co-operation, like side-transfers, issue-linking and trade-sanctions. Several authors also see countries' moral obligations and commitment as possible important factors in this.

Contrary to basic economics theory, compliance with international environmental agreements (IEAs) is the norm. Several explanations to this are possible. An IEA may be seen as the outcome of a non co-operative game, and hence only reflects each country's costs and benefits of that underlying game. Countries are free to negotiate and join the IEAs they choose, perhaps opting out of costly "deep co-operation".

To have mechanisms for efficient implementation of an IEA will make it easier for countries to join and comply. However, achieving overall efficiency seem unlikely. It requires both that targets are set optimally and the agreed measures must be implemented cost-efficiently. Mechanisms to achieve cost-efficiency exist, but have their problems.

The Kyoto Protocol opens up for such flexible mechanisms: International emissions trading (IET) and joint implementation (JI). To minimise costs of implementation measures to combat global warming must be performed also in economies in transition and developing countries, but the developing countries do not have obligations under the protocol. For JI-projects between an investor in a country with obligations and a host in a country without obligations the Kyoto Protocol includes the Clean Development Mechanism (CDM). The detailed rules for all these flexible mechanisms have not yet been agreed upon.

For IET possible problems with countries' market power in the emissions quota market, limited participation in trading, high transaction costs, asymmetric information opening up for cheating and the trade of "hot air" can reduce the cost-saving, or even lead to higher overall costs of implementation.

For JI (includes the CDM) one fears that high transaction costs, asymmetric information opening up for adverse selection of projects and hidden action by the hosts, "paper trades" due to missing emission baselines for the developing countries, limited participation and leakages will limit their cost-saving ability.

I believe JI-project investors will try to perform several projects with the same host to reduce transaction costs of each project. Due to financial constraints hosts in developing countries and economies in transition will need to get all or some of the project transfer before performing the project. In have developed two models in this thesis to investigate if JI-contracts are possible under these assumptions. I find that even if external uncertain factors can cause project failure and the host has private information opening up for cheating, contracts can be possible. To increase the chances of JI-projects the external factors' influence should be reduced. A JI-project host should work to reduce a host's private information, to avoid own benefit of the project being eliminated due to contract breach by the host.

That the developing countries have no emission limits under the Kyoto Protocol is a very large problem. The protocol's targets for emission-reductions are not permanent, but only for the period 2008-2012. What will happen thereafter is yet to negotiate. If emissions reductions obtained this period are not permanent, the whole exercise is meaningless. If the set of detailed rules for the Kyoto Protocol's flexible mechanisms, perhaps being decided at COP-6 in The Hague in November 2000, can not lead to cost-efficient implementation, it will be a major blow to the whole process of dealing with climate change. Then chances are that the protocol's overall target will not be met. In my view there is no point in negotiating targets for later periods before these other issues are resolved.

7. APPENDIX

7.1 Model calculations

7.1.1 How to determine the equilibria and conditions of the basic model

Each player can pursue one of the two pure strategies or a mixed strategy. This gives rise to nine possible combinations of types of strategies between the principal and the agent.

From Equation 21:

k) if

$$\delta G_3 < \{a_i[(1-\gamma)(B-F+\delta G_1)+\gamma(-F+\delta G_2)]+(1-a_i)[-F+\delta G_2]\}$$

then the principal sets p_i=1 for all i.

l) if

$$\delta G_3 > \{a_i[(1-\gamma)(B-F+\delta G_1)+\gamma(-F+\delta G_2)]+(1-a_i)[-F+\delta G_2]\}$$

then the principal sets p_i=0 for all i.

m) if

$$\delta G_3 = \{a_i[(1-\gamma)(B-F+\delta G_1)+\gamma(-F+\delta G_2)]+(1-a_i)[-F+\delta G_2]\}$$

then the principal sets $p_i \in [0,1]$ for all i.

From Equation 22:

r) $[(1-\gamma)(T-L+\mu H_1)+\gamma(T-L+\mu H_2)] > [T+\mu H_2] \Rightarrow a_i=1\ \forall i$.

s) $[(1-\gamma)(T-L+\mu H_1)+\gamma(T-L+\mu H_2)] < [T+\mu H_2] \Rightarrow a_i=0\ \forall i$.

t) $[(1-\gamma)(T-L+\mu H_1)+\gamma(T-L+\mu H_2)] = [T+\mu H_2] \Rightarrow a_i \in [0,1]\ \forall i$.

Earlier it was stated that if the principal does not offer an agreement to the agent, the agent will always use the environmental resource in the traditional manner. Two of the initial nine combinations can then be eliminated ((l, r) and (l, t)).

When conditions (m) and (t) hold we have the case of Equilibrium (1). When conditions (l) and (s) hold, we have the case of Equilibrium (2).

Assume conditions (m) and (t) hold. Randomisation by the principal implies $G_i=(1-p_i)\delta G_3+p_i\delta G_3=\delta G_3$ $\forall i$. Thus $G_i=0$ $\forall i$ since $\delta\neq 1$. Substituting $G_i=0$ $\forall i$ into the expression for the principal's expected payoff (Equation 21) gives a_i as in Equilibrium (1).

Condition (a) is needed for $a_i\leq 1$ (probabilities must be between 0 and 1)

Condition (t) can be rearranged to give an expression for H_1. This can be used to eliminate H_1 from the set of equations of the agent's expected payoff in the three states:

$$(1-\mu p_1)H_2-\mu(1-p_1)H_3=p_1T-\frac{L}{\mu(1-\gamma)}$$

Equation 60

$$(1-\mu p_2)H_2-\mu(1-p_2)H_3=p_2T$$

Equation 61

$$-\mu p_3H_2-(1-\mu(1-p_3))H_3=p_3T$$

Equation 62

We now have three equations in two unknowns (H_2 and H_3). The p_i's are strictly also unknowns, but by choosing the p_i's adequately, the set above can be solved for H_2 and H_3. The system will only have a solution if one of the equations is redundant. Mathematically this is the same as if the expanded coefficient matrix has a zero determinant:

$$\begin{vmatrix} (1-\mu p_1) & -\mu(1-p_1) & p_1T-\dfrac{L}{\mu(1-\gamma)} \\ (1-\mu p_2) & -\mu(1-p_2) & p_2T \\ -\mu p_3 & 1-\mu(1-p_3) & p_3T \end{vmatrix}=0$$

Equation 63

Solving this gives Equation 27 (I have used the data-program “Mathematica” for this).

Conditions (b) and (c) are necessary to ensure that $0\leq p_i\leq 1$ for all states i=1,2,3;
Equation 27 can be rearranged to give:

$$p_1 = \frac{\mu p_2\left[(1-\gamma)T - L\right] + L(1+\mu p_3)}{\mu(1-\gamma)T}$$

Equation 64

The requirement $0 \le p_1 \le 1$ puts restrictions on the right hand side of this equation:

$$0 \le \frac{\mu p_2\left[(1-\gamma)T - L\right] + L(1+\mu p_3)}{\mu(1-\gamma)T} \le 1$$

Equation 65

Since $\mu(1-\gamma)T > 0$ and p_3 is a probability:

$$p_3 \ge \frac{-\mu p_2\left[(1-\gamma)T - L\right] - L}{\mu L} \le 1$$

Equation 66

and

$$p_3 \le \frac{\mu T(1-\gamma) - L - \mu p_2\left[(1-\gamma)T - L\right]}{\mu L} \ge 0$$

Equation 67

These two last equations again puts restrictions on p_2. These restrictions leads to the necessity of conditions (b) and (c). The same restrictions are also necessary for the agent's expected payoff to be non-negative in equilibrium.

We have shown that the combination of conditions (m) and (t) gives an equilibrium, namely Equilibrium (1).

If the principal assumes the agent will exploit the resource anyway, she can do no better than not offer an agreement. With no agreement, the agent will use the resource in the traditional manner. This combination is clearly an equilibrium, namely Equilibrium (2).

Assuming the existence of an equilibrium for all other combinations of conditions (k-m) and (r-t) gives contradictions. An example will illustrate this:

Assume conditions (k) and (s) hold. Then the principal will always offer a trade agreement, and the agent will always break the agreement. Inserting this into the principal's expected payoff equation gives $G_i=(-F)/(1-\delta)$ for all i. Substituting this back delivers:

$$G_i = (1-p_i)\frac{-\delta F}{1-\delta} + p_i\,\frac{-2F+\delta F}{1-\delta}$$

Equation 68

We see that p_i=0 will maximise the expected payoff. This contradicts the initial assumption of p_i=1, and the combination of condition (k) and (s) is not an equilibrium. Similar contradictions can be found for all other combinations except the ones yielding Equilibria (1) and (2).

7.1.2 Is p_1 always larger than p_2 and p_3?

Question:
Is p_1 always larger than p_2 and p_3 in Equilibrium (1) of the basic model?

Investigation:
Try to set $p_1 = \alpha\, p_2$ in Equation 27, with $\alpha<1$. This gives

$$\mu\, p_2[(1-\gamma)T(\alpha-1)+L] = L\,(1+\mu\, p_3)$$

Equation 69

We must assume that $[(1-\gamma)T(\alpha-1)+L] > 0$ else the left hand side would be negative, and p_3 would have to be negative as well.

From Equation 69 we see that

$$\frac{\partial p_2}{\partial p_3} = \frac{L}{(1-\gamma)T(\alpha-1)+L} \quad (>0)$$

Equation 70

P_2 is hence increasing in p_3. But setting $p_3 = 0$ in Equation 69 gives

$$p_2 = \frac{L}{\mu[(1-\gamma)T(\alpha-1)+L]}$$

Equation 71

Since the denominator in Equation 71 is less than L, the value for p_2 from this equation is higher than 1.

Hence we have shown that $p_2 > p_1$ is impossible.

Now set $p_1 = \beta\, p_3$ with $\beta < 1$. From Equation 27 we then get

$$\mu p_3\,(\beta(1-\gamma)T - L) = L + \mu p_2(T(1-\gamma) - L)$$

Equation 72

We must assume that $(\beta(1-\gamma)T - L)$ is positive. If not the left-hand side will be negative, and so p_2 will have to be negative, which is impossible. We see that

$$\frac{\partial p_3}{\partial p_2} = \frac{T(1-\gamma)-L}{\beta T(1-\gamma)-L} \quad (>0)$$

Equation 73

p_3 is increasing in p_2, and setting $p_2 = 0$ in Equation 73 gives

$$p_3 = \frac{L}{\mu[\beta T(1-\gamma)-L]}$$

Equation 74

For $0 \le p_3 \le 1$ to be fulfilled, $L \ge 0$ (lower limit), and

$\beta \ge \frac{L}{\mu T(1-\gamma)} + \frac{L}{T(1-\gamma)}$ (higher limit).

Due to conditions (b) and (c) of Equilibrium (1), this implies that $\beta < 2$. Hence p_1 is not necessarily larger than p_3. For p_1 to be larger than p_3 always in Equilibrium (1) β must be smaller than 1. For this to be the case:

$T > \frac{(1+\mu)L}{\mu(1-\gamma)}$.

7.1.3 Determining the equilibria and conditions of the control model

In the basic model the two players could choose between 3 different strategies each. Each could pursue one of the two pure strategies or a mixed strategy in a_i or p_i respectively. It gave rise to nine possible combinations of strategies between the principal and the agent. In the control model the agent also has the three different options for strategy in c_i.

From Equation 36:

$$\text{If } \delta G_3 < \left\{ a_i \begin{bmatrix} (1-c_i)[(1-\gamma)(B-F+\delta G_1)+\gamma(-F+\delta G_2)] \\ +c_i[(1-\gamma^c)(B-F+\delta G_1)+\gamma^c(-F+\delta G_2)] \end{bmatrix} + (1-a_i)[-F+\delta G_2] \right\}$$

Equation 75

then the principal sets p_i=1 for all i.

$$\text{If } \delta G_3 > \left\{ a_i \begin{bmatrix} (1-c_i)[(1-\gamma)(B-F+\delta G_1)+\gamma(-F+\delta G_2)] \\ +c_i[(1-\gamma^c)(B-F+\delta G_1)+\gamma^c(-F+\delta G_2)] \end{bmatrix} + (1-a_i)[-F+\delta G_2] \right\}$$

Equation 76

then the principal sets p_i=0 for all i.

$$\text{If } \delta G_3 = \left\{ a_i \begin{bmatrix} (1-c_i)\left[(1-\gamma)(B-F+\delta G_1)+\gamma(-F+\delta G_2)\right] \\ +c_i\left[(1-\gamma^c)(B-F+\delta G_1)+\gamma^c(-F+\delta G_2)\right] \end{bmatrix} + (1-a_i)\left[-F+\delta G_2\right] \right\}$$

Equation 77

then the principal sets $p_i \in [0,1]$ for all i.

From Equation 37:

$$\text{If } \left[(1-\gamma)(T-L+\mu H_1)+\gamma(T-L+\mu H_2)\right]$$
$$< \quad \left[(1-\gamma^c)(T-L-C+\mu H_1)+\gamma^c(T-L-C+\mu H_2)\right]$$

Equation 78

$\Rightarrow c_i=1\ \forall i$.

$$\text{If } \left[(1-\gamma)(T-L+\mu H_1)+\gamma(T-L+\mu H_2)\right]$$
$$> \quad \left[(1-\gamma^c)(T-L-C+\mu H_1)+\gamma^c(T-L-C+\mu H_2)\right]$$

Equation 79

$\Rightarrow c_i=0\ \forall i$.

$$\text{If } \left[(1-\gamma)(T-L+\mu H_1)+\gamma(T-L+\mu H_2)\right]$$
$$= \quad \left[(1-\gamma^c)(T-L-C+\mu H_1)+\gamma^c(T-L-C+\mu H_2)\right]$$

Equation 80

$\Rightarrow c_i \in [0,1]\ \forall i$.

and

$$\begin{bmatrix} (1-c_i)\left[(1-\gamma)(T-L+\mu H_1)+\gamma(T-L+\mu H_2)\right] \\ +c_i\left[(1-\gamma^c)(T-L-C+\mu H_1)+\gamma^c(T-L-C+\mu H_2)\right] \end{bmatrix} > \left[T+\mu H_2\right]$$

Equation 81

$\Rightarrow a_i=1\ \forall i$.

$$\begin{bmatrix} (1-c_i)\left[(1-\gamma)(T-L+\mu H_1)+\gamma(T-L+\mu H_2)\right] \\ +c_i\left[(1-\gamma^c)(T-L-C+\mu H_1)+\gamma^c(T-L-C+\mu H_2)\right] \end{bmatrix} < \left[T+\mu H_2\right]$$

Equation 82

$\Rightarrow a_i=0\ \forall i$.

$$\begin{bmatrix}(1-c_i)\left[(1-\gamma)(T-L+\mu H_1)+\gamma(T-L+\mu H_2)\right]\\+c_i\left[(1-\gamma^c)(T-L-C+\mu H_1)+\gamma^c(T-L-C+\mu H_2)\right]\end{bmatrix}=\left[T+\mu H_2\right]$$

Equation 83

$\Rightarrow a_i\in[0,1]\ \forall i$.

Some of the possible combinations of strategies can be eliminated because we have assumed that:

i) If the principal does not offer the agent an agreement, the agent will always use the resource in the traditional manner (a_i=0, and the principal will observe what she defines as misuse of the resource).

ii) If the agent will misuse the resource anyway, we have assumed there is no point in her exerting control, as the principal can only observe whether misuse has taken place, and not the amount of it nor who is responsible.

Just like for the basic model we must assume one set of strategies valid, and check whether it will give any contradictions. If not, we have an equilibrium. I will here only go through the combinations that actually give equilibria.

Assume p_i=0 and a_i=0 (then c_i is assumed to be 0 always) (Equilibrium (C4)):

If the agent will always misuse the resource, then the principal can do no better than to not offer the agent an agreement. If the principal never will offer an agreement to the agent, then the agent can do no better than to always misuse the resource. This is clearly an equilibrium.

Assume $p_i\in[0,1]$, $a_i\in[0,1]$, and c_i=0 (Equilibrium (C1)):

When $p_i\in[0,1]$ then we have from Equation 36 that $G_i=\delta G_3$ for all i. Since $\delta \neq 1$ this must imply that G_i=0 for all i. The condition for c_i=0, is found from Equation 79:

$$H_1 < H_2 + \frac{C}{\mu(\gamma-\gamma^c)}$$

Equation 84

When c_i=0, and $a_i\in[0,1]$, another expression of the relationship between H_1 and H_2 can be found from Equation 83:

$$H_1 = H_2 + \frac{L}{\mu(1-\gamma)}$$

Equation 85

This implies:

$$C \quad > \quad \frac{L(\gamma-\gamma^c)}{(1-\gamma)}$$

Equation 86

Equation 77 can be solved for a_i when G_i=0 and c_i=0.

The expression in Equation 85 can be used to eliminate H_1 from the set of equations given by Equation 37 for i=1,2,3. This set of 3 equations in H_2 and H_3 will only have a solution if one of the equations is redundant. This means that the expanded coefficient matrix from the set of equations must have determinant zero. This will give the expression that defines the principal's strategy. In this case it is identical to Equation 63, which leads to the principal's strategy in the basic model.

Assume $p_i \in [0,1]$, $a_i \in [0,1]$, and c_i=1 (Equilibrium (C2)):

The condition for the agent to choose c_i=1 when $a_i \in [0,1]$ is

$$C \quad < \quad \frac{L(\gamma-\gamma^c)}{(1-\gamma)}$$

Equation 87

When c_i=1 and G_i=0 $\forall$i Equation 77 can be solved for a_i.

From Equation 83 with c_i=1 we find that:

$$H_1 = H_2 + \frac{L+C}{\mu(1-\gamma^c)}$$

Equation 88

In he same manner as earlier this can be used to eliminate H_1 from the set of 3 equations given by Equation 37 for i=1,2,3. The 3 equations in H_2 and H_3 can again be used to find the principal's strategy. By comparing Equation 88 and Equation 85 we can however easily find the principal's strategy without going through the whole exercise of setting the determinant of the expanded coefficient matrix equal to zero and solving for p_i.

Assume $p_i \in [0,1]$, $a_i \in [0,1]$, and $c_i \in [0,1]$ (Equilibrium (C3)):

The condition for the agent to set $c_i \in [0,1]$ when $a_i \in [0,1]$ is:

$$C \quad = \quad \frac{L(\gamma-\gamma^c)}{(1-\gamma)}.$$

Equation 89

With mixed strategies in both a_i and c_i, we can get a_i expressed as a function of c_i from Equation 36 (and vice versa), as it is in Equilibrium (C3). Since both a_i and c_i are probabilities, condition (j) must be valid.

From Equation 83 with $c_i \in [0,1]$ we can get either the same expression as in Equation 88 or as in Equation 85 to eliminate H_1 from the set of 3 equations given by i=1,2,3 from Equation 36. We understand that the principal's strategy must satisfy the relevant conditions from both Equilibrium (C1) and (C2) (conditions c-d and g-h). Due to condition (i) of Equilibrium (C3) (same as Equation 87), condition (c) is equivalent to (g), and (d) to (h).

7.2 Abbreviations

In the chapter on International Environmental Agreements:

Annex B – Annex B to the Kyoto Protocol, listing the countries with obligations to reduce their emissions of greenhouse gases, including the target. The countries are roughly the same as in Annex I of the FCCC, but with the EU also as a separate party.

Annex I – Annex I to the Framework Convention on Climate Change, containing roughly a list of the developed countries (OECD countries and the economies in transition in Central and Eastern Europe, including Russia).

Annex II – Annex II to the Framework Convention on Climate Change, containing a list of the "rich" countries (most of the OECD countries)

CDM – The Clean Development Mechanism

COP – Conference of the Parties

EIT – Economies in transition, referring to Russia and Central and Eastern European states.

FCCC – The UN's Framework Convention on Climate Change

GDP – Gross Domestic Product

IEA – International Environmental Agreement

IET – International Emissions Trading

JI – Joint implementation

In the models:

a_i – the agent's state-dependent strategy (frequency) to not change behaviour (misuse the resource)

A – agent (JI-project host)

B – the benefit to the principal if the resource is not misused/the JI-project is performed successfully

F – the principal's cost of making a transfer to the agent

G_i – the principal's expected payoff of being in state i

H_i – the agent's expected payoff of being in state i

i – indicates the state-dependence of a variable

L – the cost (loss) to the agent of changing behaviour

p_i – the principal's state-dependent strategy (frequency) to offer the agent a new contract

P – principal (JI-project investor)

T – the benefit to the agent of receiving the transfer from the principal

δ – the principal's discount factor

γ – the probability that factors others than the agent will cause misuse/project failure

γ^c – the probability that factors other than the agent will cause misuse/project failure, when the agent exerts control over these factors

μ – the agent's discount factor

8. LITERATURE

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E.