37

■

Optimal and Stable International Climate Agreements

Johan Eyckmans and Henry Tulkens

October 2005

ENVIRONMENTAL
ECONOMICS & MANAGEMENT
MEMORANDUM

UCL
Université
catholique
de Louvain

Chair Lhoist Berghmans
in Environmental Economics
and Management

Center for Operations Research
and Econometrics (CORE)

Environmental Economics and Management Memorandum # 37

Optimal and Stable International Climate Agreements

Johan Eyckmans
EHSAL
and CES - KULeuven

Henry Tulkens
CORE
Université catholique de Louvain

Reprint from

Economic Aspects of Climate Change Policy
A European and Belgian Perspective

A joint product of CES-K.U.Leuven and CORE-UCL
Edited by Bert Willems, Johan Eyckmans and Stef Proost

Published by ACCO
Brusselsestraat 153, 3000 Leuven (Belgium)

With the financial support of the Belgian Science Policy
Contract CP/10

2005

III. Optimal and Stable International Climate Agreements

Johan Eyckmans and Henry Tulkens

1 INTRODUCTION

In this chapter we will focus on the *intragenerational* (i.e. within one generation) cooperation problem. We leave aside the *intergenerational* (i.e. over several generations) aspects, which were treated in chapter 2. Our two main questions are, first, what is the optimal effort level and burden sharing for an international climate agreement? Secondly, what incentives do countries have to ratify and obey such an optimal agreement?

We start by comparing two extreme forms of international climate policy coordination. On the one hand there is the so-called *national optimum* which is characterized by the complete absence of cooperation. Countries undertake some modest greenhouse gas emission reductions but they are only motivated by national self-interest. On the other hand we will show how a *World optimum* global climate treaty should look like in terms of overall emission ceiling and distribution of efforts among the signatories.

We then argue that countries will sign an international climate agreement only if it is in their best interest to do so. Some simulation results will be used to illustrate the fact that a grand agreement comprising all countries of the world will probably not be stable because some countries would individually lose from it compared to their national optimum.

Finally, we turn to monetary transfers as a way to counter these deviation threats. We will discuss and illustrate two recent transfer schemes that can induce stable international cooperation, each based on a different notion of stability. While keeping theoretical concepts and results to a minimum, we also make use of numerical simulation results to illustrate some of the points we want to make. We conclude with a few policy recommendations, derived from our research, on the design of future climate agreements, namely those concerning the Second Commitment period of the U.N.F.C.C.C., i.e. the so-called Post-Kyoto negotiation round which is due to start soon.

2 OPTIMAL INTERNATIONAL CLIMATE AGREEMENTS

2.1 The challenge: greenhouse gas emission reduction is a public good

For economists, reducing emissions of greenhouse gases is an example of providing a pure public good. Public goods are *non-excludable* in the sense that no one can be excluded from enjoying the benefits they generate. Applied to the case of the emission reductions agreed upon in the 1997 Kyoto Protocol, this means, for instance, that the United States, which signed but did not ratify the treaty, cannot be prevented from enjoying the benefits of the Kyoto Protocol, i.e. the lower rate of climate change if the ratifying signatories meet their promises. Excluding the United States from these benefits would require building a huge dome over American territory letting a slightly higher level of greenhouse gases concentration develop inside. This illustrates the technical (and economic) impossibility of excluding countries from the benefits of the global public good.

It is a well-known economic insight that non-excludability causes public goods to be under-provided. Consider Table 1 representing the rewards that an individual country like the United States can obtain from ratifying an international climate agreement, in function of the ratification decisions of the other countries, in particular the European Union.

Table 1: To Ratify or Not to Ratify

		European Union	
		Ratify	**Not Ratify**
United States of America	**Ratify**	**3** World optimum	**1** free riding by EU
	Not Ratify	**4** free riding by USA	**2** national optimum

The numbers in the cells of Table 1 are to be interpreted as the preference ranking of the United States of the alternative scenarios. The higher the number, the more the USA likes the scenario. Consider first the top-left cell in which all countries, including the USA, ratify the climate treaty. This scenario will be labelled *World optimum* in the sequel, since it refers to the case where all countries cooperate to slow down climate change.

The World optimum is preferred by the USA over the scenario in which no country would ratify the treaty and climate change would cause substantial damages (bottom-right cell). The scenario in which countries do not cooperate to limit their greenhouse gas emissions will be labelled *national optimum* in the sequel. The USA has to perform no emission abatement effort in the latter case, but it would experience considerable climate change damages in the future because there is no effective climate policy.

The USA prefers most the situation in which all other countries ratify the treaty and contribute to combat climate change, while the USA does nothing (bottom-left). This scenario is called *free riding* by the USA. Because the benefits are non-excludable, the USA can benefit from a lower level of climate change without itself contributing to the global efforts. This situation is most preferred because it entails no domestic emission reduction efforts and a very similar level of climate change compared to the scenario where the USA would join the climate treaty.

From the individual perspective of the USA, the worst of all configurations is where it would act alone against climate change without any other country following its example (top-right cell). The USA would incur considerable emission reduction costs but would not be able on its own to slow down climate change.

Table 1 clearly demonstrates that the dominant strategy for the USA is *not* to ratify the climate protocol. This strategy ensures the highest payoff, irrespective of what the European Union does. But the same picture holds not only for the USA and EU but for every other individual nation faced with the decision of whether to to ratify a future climate agreement. We conclude that no country has an incentive to ratify the climate treaty: all hope that the others will bear the burden and provide the global public good. This behaviour is called free riding in economics, i.e. enjoying a bus ride without paying for the ticket. Free riding behaviour is not only a theoretical construction: it is also frequently observed in social experiments, including the context of international environmental agreements[1].

After this rather pessimistic conclusion regarding ratification of an international climate agreement, one might get the impression that there is no hope for sustainable international cooperation in the field of climate policy. However, in 1997, the Kyoto Protocol was signed and after a long ratification trajectory it has finally come into force on February 16, 2005. Hence, reality seems at odds with Table 1. The reason for this apparent anomaly is that the table ignores most of the complicated problems: in reality, more than two countries are involved and they usually differ significantly in terms of climate change impacts, GHG emissions and economic development. We will therefore investigate the economic arguments for the difficulties in negotiations and offer suggestions for how an optimal global climate treaty might be reached. We start in section 2.2 with the national optimum scenario, and then turn in section 2.3 to the World optimum case.

[1] Barrett (2003) reports that in classroom experiments that mimic the formation of international environmental agreements, typically between one third and two thirds of participants are free riders.

2.2 Nationally optimal level of emissions

For the purpose of the analysis we will make use of a model that strongly resembles the benefit-damage model of chapter 2 but distinguishes between countries rather than generations. Thus, the time dimension is eliminated and replaced by regional differences. In particular, we assume that every country chooses a GHG emission level in order to maximize its national welfare function:

$$\max_{e_i} \quad W_i\left(e_i, e_W\right) = B_i\left(e_i\right) - D_i\left(e_W\right) \tag{1}$$

Welfare in country i is defined as the difference between benefits B_i of individual emissions e_i minus damages D_i caused by global emissions $e_W = \sum_{j \in W} e_j$. By W we denote the set of all countries in the world. The interpretation of the benefit and damage functions are identical to those in Chapter 2, though the context is a static rather than dynamic one. Notice that damages are a function of the unweighted sum of all countries' emissions; namely, what matters for the problems of climate change is not who emits greenhouse gases, but only the overall quantity of emissions.

Individual welfare optimization leads to the following characterization of individual countries' behaviour in the national optimum[2] (*NO* in the sequel) scenario:

$$B_i'(e_i^{NO}) = D_i'\left(e_W^{NO}\right) \tag{2}$$

This condition states that every country will let its emissions reach a level e_i^{NO} such that the national benefits from the last ton emitted exactly equals the national damages it entails. Emitting more would yield more climate change damages than benefits from additional consumption goods and services and would therefore not be rational. Similarly, national welfare would decrease in the country that would emit less than e_i^{NO} . In this case, the valuation of additional consumption goods and services exceeds the additional future climate change caused by the production of these additional goods and services.

For later reference, we will denote the welfare level of a particular country i in the national optimum by $W_i^{NO} = W_i\left(e_i^{NO}, e_W^{NO}\right)$.

2.3 World optimal level of emissions

It is intuitively clear that the national optimum will not be optimal from the point of view of global society. Every country reduces its emissions somewhat but it

[2] Technically, there are as many conditions as there are countries. The national optimum emission levels are the simultaneous solution to this set of conditions. The resulting outcome is known in economics as a Nash-equilibrium. We refer the interested reader to Eyckmans, Proost and Schokkaert (1993) for more technical details.

only takes into account national damages and ignores spill-over effects to neighbouring countries. But what then would be the World optimal amount of emission abatement for an international environmental externality problem like climate change? This question is addressed in section 2.3.1. Given an answer to the previous question, section 2.3.2 shows how this overall emission reduction effort should be allocated over the different countries in the world.

2.3.1 Internalizing climate change damages

Defining a globally optimal outcome is by definition a normative exercise that requires one to start with the specification of an objective to be pursued by society. Economists often use the concept of *Pareto efficiency* as a normative objective for society. Loosely speaking, a situation is said to be Pareto efficient if it is impossible to improve the well-being of one person (or country) without deteriorating the position of other persons (countries).

Pareto efficiency is an appealing normative concept for two reasons. First, it entails the idea that resources should not be wasted, i.e. all available opportunities to promote the well-being of all should be exploited. Secondly, it refers to an idea of unanimity. If someone is worse off in the move from one situation to another, the Pareto criterion gives this person a veto to stop the move. Technically, Pareto efficient allocations can be identified by maximizing the sum[3] of all countries' welfare functions:

$$\max_{e_1,\ldots,e_n} \sum_{j\in W} W_j\left(e_j, e_W\right) \tag{3}$$

The solution of this maximisation problem — emission levels e_i^{WO} for each country — must satisfy the following first-order conditions:

$$B_i'(e_i^{WO}) = \sum_{j\in W} D_j'\left(e_W^{WO}\right) \tag{4}$$

This rule has two important implications. First, in the *World optimum* (*WO* in the sequel), emissions are a function of the sum of all climate change damages. In contrast, in the national optimum, only domestic damages were taken into account in every country's emission decision. We therefore say that in the World optimum, external damages of greenhouse gas emissions are perfectly internalized. For later reference, we will denote the welfare level of a particular country *i* in the World optimum by $W_i^{WO} = W_i\left(e_i^{WO}, e_W^{WO}\right)$.

2.3.2 Cost efficient burden sharing

Secondly, conditions (4) imply that:

---

[3] Attaching equal weight to each country is not as straightforward as it may seem at first sight. In order to use equal weights, one has to assume either that unrestricted monetary transfers are possible or that all citizens of the world attach equal value to an additional € of consumption. As an alternative, Eyckmans, Proost and Schokkaert (1993) use a weighted societal objective function with weights that are inversely proportional to the countries' per capita GDP.

$$B_i'(e_i^{WO}) = B_j'(e_j^{WO}) \quad (5)$$

for any pair of countries *i* and *j*. Hence, the benefit of the last ton emitted should be the same for all countries. In other words, interpreted in terms of emission restrictions, the cost of the last ton of greenhouse gasses cut should be equalized over all countries. This rule is known as *cost efficiency*. Cost efficiency means that it is impossible to decrease the total cost of the global emission reduction target by altering the burden sharing. If countries differ in abatement costs, cost efficiency requires some differentiation of abatement targets. In particular, low cost countries should perform relatively more effort than high cost countries.

2.4 Summary on optimal international climate agreement

- Every country faces a strong free riding incentive when it has to decide on ratifying a climate agreement. Since no country can be excluded from the benefits of such an agreement, every country has an incentive not to ratify and hope the others will do the effort.
- It is in every country's self-interest to undertake some emission abatement, even in the absence of international environmental agreements.
- The degree of domestic emission control in the national optimum is a function only of (expected) future marginal climate change damages within the country itself.
- Compared to the national optimum, emissions in the World optimum should be a function of the sum of all countries' climate change damages. This principle is called internalisation of damages.
- Typically, emissions in the World optimum are lower than in the national optimum.
- The optimal burden sharing leads to equalization of marginal emission abatement costs. This principle is called cost efficiency and means that overall emission reduction target cannot be achieved at a lower total cost by reshuffling emission reduction efforts.

3 STABLE INTERNATIONAL CLIMATE AGREEMENTS

3.1 Winners and losers from cooperation without transfers

Although total welfare in the World optimum is higher than in the national optimum, it need not necessarily be the case that every individual country gains from an optimal global climate agreement. In order to illustrate this point, we use some numerical results obtained from the CLIMNEG World Simulation (CWS in the sequel) model. This model was built by the authors in the framework of the Belgian CLIMNEG research network[4] and has been used extensively for game theoretic analysis of climate agreements. More details on this model are provided in Eyckmans and Tulkens (2003).

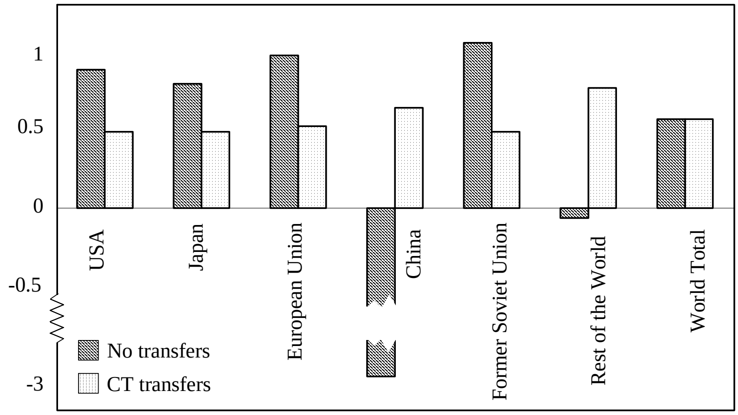

Figure 1: Winners and Losers in World optimum with and without transfers compared to national optimum

The striped bars in Figure 1 show the percentage difference between the individual regions' welfare levels at the World optimum and at the national optimum. Welfare is measured as the discounted value of the lifetime consumption flow; the underlying emission allocations satisfy conditions similar to (2) and (4) in a dynamic model optimized over a horizon of several centuries.

On the right of the figure note first the positive gain of cooperation for the World as a whole. Individually, however, China suffers significant losses. The intuitive explanation for this is as follows. It is generally assumed that GHG emission abatement costs in China are low because of its obsolete industrial infrastructure and energy plants. Replacing old coal-fired power plants by new more efficient gas-fired power plants would be a relatively cheap way to save emissions in China. On the other hand, it is believed that China does not value much the potential climate change damages to its economy. Hence, in the national optimum, China would choose for a relatively high emission level, or equivalently, low emission abatement effort. However, in a cost efficient global emission arrangement, China would be required to reduce emissions significantly because its reduction costs are so low.

Also RoW (Rest of the World) is slightly worse off in the grand climate agreement compared to the national optimum. From Figure 1 it is clearly not surprising that China and RoW (which includes Brazil and India) did not want to adopt quantified emission ceilings for the First Commitment Period of the U.N.F.C.C.C., i.e. the Kyoto Protocol. These countries are bound to lose in a cost efficient international climate agreement since they have to perform a lot of

[4] The CLIMNEG (1997-2001) and CLIMNEG 2 (2002-2005) projects were funded by the Belgian Federal Science Policy Office, see http://www.climneg.be .

abatement effort and the resulting costs are only partially compensated for by lower climate change damages.

3.2 Transfers to stabilize international climate agreements

3.2.1 Why transfers can help

In the discussion thus far we have argued that countries will be willing to sign (and comply with) an international climate agreement only it they feel it is in their best interest to do so. Turning this around, we consider that the design of the agreement should take into account that countries are not always altruistic when it comes to bearing the costs of providing a better environment, especially if the benefits are enjoyed (partly) by other countries and other generations. In the remainder of this chapter we discuss other aspects of future climate agreements relating to their stability, which is endangered by various forms of free riding behaviour. In particular, we consider whether resource transfers between the signatories can enhance stability.

Note that we will only use transfers to mitigate free riding incentives and not to pursue any normative or ethical objective. Hence we focus on the incentive problem only. Chapter 4 of this book gives a more extensive discussion (with numerical illustrations) of ethically inspired transfer schemes in the context of international climate agreements.

3.2.2 Chander-Tulkens transfers

Consider a proposed global climate treaty that would implement the overall emission level and distribution of effort implied by the World optimum in condition (4). Without any additional monetary transfers, this agreement would yield a positive global surplus of cooperation but some individual countries might be worse off compared to the national optimum, as we have seen (e.g. China in Figure 1).

Chander and Tulkens (1995, 1997) have suggested a transfer scheme to mitigate this problem. They suggest reallocating the surplus of cooperation such that after transfers, each country achieves the following welfare level:

$$W_i^{CT} = W_i^{NO} + \delta_i \, \Delta_W^{NO} \tag{6}$$

in which $\Delta_W^{NO} = \sum_{j \in W} \left[W_j^{WO} - W_j^{NO} \right]$ stands for the joint global surplus of cooperation at the World optimum compared to the national optimum, i.e. the striped bar labelled “World Total” in Figure 1. In words, the Chander-Tulkens transfer scheme ensures that each country enjoys at least its national optimum welfare level W_i^{NO} and on top of that lower bound, each one receives a positive share δ_i of the global surplus from cooperation Δ_W^{NO}. Hence, all will be better off than in the national optimum. This property is called *individually rationality*.

Chander and Tulkens (1995, 1997) have shown a remarkable property of a particular version of this transfer formula. If one chooses the surplus sharing weight δ_i for each i such that it reflects the share of the country in the total marginal climate change damages, the resulting allocation is not only individually rational but also *coalitionally rational*. This last property means that no subgroup of countries can suggest a *partial* or incomplete climate agreement making all of its members better off than under the global agreement with the above transfers[5]. In this sense, the Chander-Tulkens transfer formula provides stability to a global climate agreement comprising all countries of the world.

Returning to Figure 1, the spotted bars show the welfare differences after applying the Chander-Tulkens transfer formula to the grand coalition. As can be seen, all countries are now receiving more than their national optimum welfare level (there are the positive spotted bars). Moreover, we can see who is paying and who is receiving transfers by comparing the striped and the spotted bars: the developed countries United States, Japan, European Union and Former Soviet Union are paying to China and Rest of the World. However, no one country is paying so much that it would be driven below its national optimum welfare level. For the numbers underlying Figure 1, Eyckmans and Tulkens (2003) have shown that the transfer allocation is not only individually, but also coalitionally rational.

3.2.3 Eyckmans-Finus transfers

Parallel to the stability result just discussed, other authors are challenging the stability concept underlying the proposed sharing rule. Indeed the stability notion involved rests on the assumption that, if a country or a group of countries objects to the proposed global climate agreement and moves to partial agreement, the other countries abandon the proposed agreement too and return to their national optimum position[6].

An alternative assumption is that it might be in the best interest of the remaining signatories to continue cooperating but with one or two members less. It is in this spirit that authors like Barrett (1994) and Carraro and Siniscalco (1993) advocate that climate agreements should be both *internally stable*, i.e. none of the members should have an incentive to leave, and *externally stable*, i.e. no outsider should have an incentive to join.

The concept of internal stability better captures the idea of free riding incentives. It corresponds to the position we explained in section 2.1 in which a country enjoys the benefits of a climate agreement without contributing effort itself. It should be intuitively clear that these free riding incentives are typically very high in the context of non-excludable public goods. It then comes at no surprise that the literature initiated by Carraro and Siniscalco (1993) and Barrett (1994) finds international environmental agreements stable in this sense only for very small groups of countries. Finus (2001) offers an excellent survey of the different stability concepts and results to be found in the literature.

---

[5] Technically, the allocation after transfers belongs to the “gamma-core” of the global greenhouse gas emission game, as formulated in Chander and Tulkens (1995, 1997).

[6] Chander (2003) shows that if players are farsighted, it is in their self-interest to leave a suboptimal coalition after deviation by a free rider. Each remaining coalition member has this incentive and hence, the agreement would dissolve completely.

Recently, Eyckmans and Finus (2005) have presented a new transfer scheme which is designed to counter these free riding incentives: the *Almost Ideal Sharing Scheme*. In order to explain what this means, considers an international climate agreement comprising only a subset *S* of all countries in the World as is the case in the 1997 Kyoto Protocol. The idea behind AISS is simple: give every member of *S* at least its free rider payoff, and distribute the remaining surplus, if any, proportionally to the members:

$$\delta_i \; W_i^{AISS} = W_i^{FR} + \delta_i \; \Delta_S^{FR} \tag{7}$$

where W_i^S stands for the welfare level country *i* can achieve while joining the climate agreement *S* and W_i^{FR} stands for its Free Riding payoff, referring to the scenario where *i* has left coalition *S* and the remaining members of *S* minus *i* continue to cooperate[7]. We denote by $\Delta_S^{FR} = \sum_{j \in S} \left[W_j^S - W_j^{FR} \right]$ the sum of the differences between these welfare levels. The surplus sharing weights may be any value, as long as they are all positive and sum up to one.

A remarkable property of AISS is that, given any potentially internally stable agreement, it can be shown to stabilize the coalition of members, not only internally (by construction), but also externally. Potentially internally stable agreements are coalitions that generate sufficient cooperation surplus to cover the free riding claims of all of its members, i.e. coalitions for which the surplus Δ_S^{FR} is positive. In other words, AISS maximizes global welfare under the constraint that climate policies are to be implemented by an internally and externally stable agreement.

3.3 An application to the Kyoto coalition

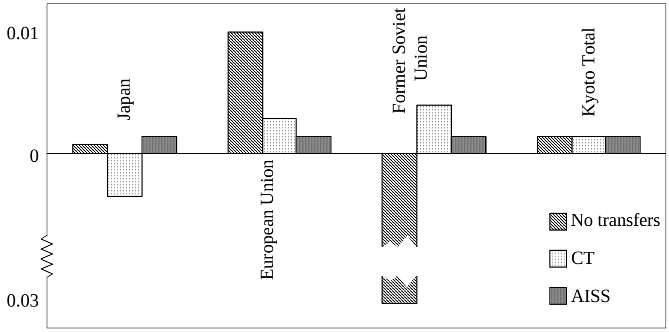

Figure 2: Winners and losers in different transfer scenarios compared to free riding payoffs

---

[7] The emission allocation under such a partial cooperation scenario is modelled as a Partial Agreement Nash Agreement as in Chander and Tulkens (1995, 1997). It is basically a mixture of the optimality conditions (2) for the outsiders to the agreement and conditions (4) for the members although they only internalize damages to their members. Hence the sum of damages only bears on S instead of N.

Figure 2 is similar in spirit to Figure 1 but it compares welfare levels of the ratifying members of the Kyoto Protocol under different transfer schemes: No Transfers, Chander-Tulkens transfers (CT) and Almost Ideal Sharing Scheme transfers (AISS), with the free riding payoffs of the same signatories. By ratifying members of the Kyoto Protocol we mean the coalition consisting of Japan, European Union and Former Soviet Union. For the six region aggregation of the CWS model, this coalition is closest to the actual Kyoto Protocol since USA has decided not to ratify. The welfare levels computed with the CWS model are the results of an intertemporal optimization, assuming that the Kyoto coalition continues for ever and implements emission strategies that maximize their group welfare. This is obviously a more comprehensive treaty than the actual protocol, which only specifies emission targets for the First Commitment period 2008-2012.

The striped bars denote the percentage difference between the Kyoto welfare levels without transfers (No transfers) and the free riding payoffs. It turns out that Japan and EU are better off with the treaty compared to their free riding position. However, the Former Soviet Union faces a strong free riding incentive. It is worse off joining the protocol compared to a free riding scenario.

The spotted bars (CT) show the percentage differences between Kyoto welfare levels, including Chander-Tulkens transfers applied to the Kyoto coalition, and free riding payoffs. Recall that the Chander-Tulkens rule guarantees every signatory its national optimum outcome (i.e. complete absence of cooperation) and a positive share of the cooperation surplus. The Chander-Tulkens transfer scheme induces internal stability for the Former Soviet Union. However, it creates a new free riding incentive for Japan. In order to keep FSU on board, Japan and EU have to pay heavily in the Chander-Tulkens transfer—so much so that Japan is driven below its free riding payoff.

The vertically striped bars (AISS) show the payoff differences for the AISS transfers. Note that all signatories are better off in the agreement compared to their free riding payoffs. Hence, no insider wants to deviate under AISS. Note that this is possible because the Kyoto coalition creates enough group surplus to compensate for the members' free riding claims: see the bar labelled "Kyoto Total" at the right in Figure 2. Jointly, there is enough surplus to stabilize, in the internal sense, this Kyoto coalition.

Finally, it should be stressed that the AISS transfer scheme is also cable of stabilizing other coalitions, in particular the four-player coalition consisting of United States, European Union, China, and Rest of the World. This coalition achieves a global World welfare level that closes the gap between the World optimum and the national optimum by 94.5% (versus only 2.9% for the Kyoto coalition in Figure 2!). Using the data of the CWS model, it is not possible to achieve an internally and externally stable climate agreement that performs better. More details on this simulation exercise comparing AISS to other transfer schemes are to be found in Carraro, Eyckmans and Finus (2005).

3.4 Summary on stable international climate agreements

- Without monetary transfers, some individual countries might lose from the World optimal climate agreement although there is a positive surplus for the world as a whole. This problem is most acute for those developing countries characterized by relatively low emission abatement costs and little regard for climate change damages.
- Monetary transfers (e.g. under the form of permit trading) can help to mitigate free riding incentives in climate agreement.
- The Chander-Tulkens transfer scheme is capable of stabilizing the grand coalition consisting of all countries in the World, provided that there exists a sufficiently credible threat that the climate agreement completely dissolves after defection by a free rider.
- The Almost Ideal Sharing Scheme is capable of stabilizing the coalition that achieves highest global welfare among all coalitions that generate sufficient surplus to compensate the free riding claims of its members. Typically, this will be an incomplete climate agreement consisting only of a subset of countries.
- Numerical simulations with the CWS model reveal that the current Kyoto Protocol coalition could be stabilized by means of appropriately chosen transfers. However, better performing coalitions than the current Kyoto coalition in terms of global welfare are achievable. Typically, they comprise cheap abatement producers like China.

4 CONCLUSIONS

In this chapter we have focussed on the intragenerational problem of international climate policy cooperation. We have distinguished between: (1) the national optimum in which countries only take into account their national damages when choosing emission levels; and (2) the World optimum in which climate change externalities are perfectly internalized and the resulting emission reduction burden is shared in a cost efficient way.

Without transfers, the World optimal global climate agreement might leave some countries worse off compared to the national optimum, in particular those countries characterized by relatively low emission abatement costs and low climate change damages. In order to keep them on board in the climate boat, some compensating transfers are required. We showed how two transfer schemes--one by Chander and Tulkens, the other by Eyckmans and Finus--rely on different notions of what a “stable” or “self-enforcing” global climate agreement means. Both schemes, however, show the important role transfers have to play in the design of stable international climate agreements.

In the Kyoto protocol there are only limited provisions for monetary transfers. It has been shown[8], however, that any transfer scheme of the kind advocated here can be implemented by an appropriate initial allocation of emission permits accompanied by competitive free trade of these permits worldwide. This is thus another virtue of the tradable permits that are handled in Chapters 4, 5 and 6 of this book.

5 REFERENCES

Barrett, S. (1994). *Self-Enforcing International Environmental Agreements*. Oxford Economic Papers 46, 804-878.

Barrett, S. (2003). *Environment and Statecraft: The Strategy of Environmental Treaty-Making*. Oxford and New York: Oxford University Press.

Carraro, C., Eyckmans, J. and Finus, M. (2005). *Exploring the Full Potential of Transfers for the Success of International Environmental Agreements*. CLIMNEG Working Paper 78. K.U.Leuven, Centrum voor Economische Studiën, Leuven.

Carraro, C. and Siniscalco, D. (1993). *Strategies for the International Protection of the Environment*. Journal of Public Economics 52, 309-328.

Chander, P. (2003). *The γ-Core and Coalition Formation*. CORE Discussion Paper 2003/46. Université Catholique de Louvain, CORE, Louvain-la-Neuve.

Chander, P. and Tulkens, H. (1995). *A Core-Theoretic Solution for the Design of Cooperative Agreements on Transfrontier Pollution*. International Tax and Public Finance 2, 279-93.

Chander, P. and Tulkens, H. (1997). *The Core of an Economy with Multilateral Environmental Externalities*. International Journal of Game Theory 26, 379-401.

Chander, P., Tulkens, H., van Ypersele, J-P. and Willems, S. (2002). *The Kyoto Protocol: An Economic and Game Theoretic Interpretation*. Chapter 6 in B. Kriström, P. Dasgupta, and K.-G. Löfgren (eds), *Economic Theory for the Environment: Essays in Honour of Karl-Göran Mäler* (pp.98-117). Cheltenham: Edward Elgar.

Eyckmans, J., Proost, S. and Schokkaert, E. (1993). *Equity and Efficiency in Greenhouse Negotiations*. Kyklos 46, 363-97.

Eyckmans, J. and Tulkens, H. (2003). *Simulating Coalitionally Stable Burden Sharing Agreements for the Climate Change Problem*. Resource and Energy Economics 25, 299-327.

Eyckmans, J. and Finus, M. (2004). *An Almost Ideal Sharing Scheme for Coalition Games with Externalities*. CLIMNEG Working Paper 62. K.U.Leuven, Centrum voor Economische Studiën, Leuven.

---

[8] Here, the work of Chander, Tulkens, van Ypersele and Willems (2002) has been more fully developed by van Steenberghe (2004).

Finus, M. (2001). *Game Theory and International Environmental Cooperation.* Cheltenham: Edward Elgar.

van Steenberghe, V. (2004). *Core-Stable and Equitable Allocations of Greenhouse Gas Emission Permits*. *CORE Discussion Paper* 2004/75. Center for Operations Research and Econometrics, Université catholique de Louvain, Louvain-la-Neuve.

Environmental Economics & Management Memoranda

38. Paul-Marie BOULANGER and Thierry BRECHET. Models for policy-making in sustainable development: The state of the art and perspectives for research. November 2005.

37. Johan EYCKMANS an Henry TULKENS. Optimal and Stable International Climate Agreements. October 2005. Reprint from "*Economic Aspects of Climate Change Policy : A European and Belgian Perspective*", a joint product of CES-K.U.Leuven and CORE-UCL, edited by Bert Willems, Johan Eyckmans and Stef Proost, published by ACCO, 3000 Leuven (Belgium)

36. Thierry BRECHET and Benoît LUSSIS. The Clean Development Mechanism in Belgian Climate Policy. October 2005. Reprint from "*Economic Aspects of Climate Change Policy : A European and Belgian Perspective*", a joint product of CES-K.U.Leuven and CORE-UCL, edited by Bert Willems, Johan Eyckmans and Stef Proost, published by ACCO, 3000 Leuven (Belgium)

35. Vincent VAN STEENBERGHE. The impact of banki!ng on permits prices and compliance costs. October 2005. Reprint from "*Economic Aspects of Climate Change Policy : A European and Belgian Perspective*", a joint product of CES-K.U.Leuven and CORE-UCL, edited by Bert Willems, Johan Eyckmans and Stef Proost, published by ACCO, 3000 Leuven (Belgium)

34. Johan EYCKMANS, Denise VAN REGEMORTER and Vincent VAN STENBERGHE. Kyoto-permit prices and compliajce gosts: an analysis with MacGEM. October 2005. Reprint from "*Economic Aspects of Climate Change Policy : A European and Belgian Perspective*", a joint product of CES-K.U.Leuven and CORE-UCL, edited by Bert Willems, Johan Eyckmans and Stef Proost, published by ACCO, 3000 Leuven (Belgium)

33. Johan EYCKMANS, Bert WILLEMS and Jean-Pascal VAN YPERSELE. Climate Change: Challenges for the World. October 2005. Reprint from "*Economic Aspects of Climate Change Policy : A European and Belgian Perspective*", a joint product of CES-K.U.Leuven and CORE-UCL, edited by Bert Willems, Johan Eyckmans and Stef Proost, published by ACCO, 3000 Leuven (Belgium)

32. Marc GERMAIN, Stef PROOST and Bert SAVEYN. The Belgian Burden Sharing. October 2005. Reprint from "*Economic Aspects of Climate Change Policy : A European and Belgian Perspective*", a joint product of CES-K.U.Leuven and CORE-UCL, edited by Bert Willems, Johan Eyckmans and Stef Proost, published by ACCO, 3000 Leuven (Belgium)

31. Ingmar SCHUMACHER. Reviewing Social Discounting within Intergenerational Moral Intuition. June 2005.

30. Stephane LAMBRECHT. The effects of a demographic shock in an OLG economy with pay-as-you-go pensions and property rights on the environment: the case of selfish households. January 2005.

29. Stephane LAMBRECHT. Maintaining environmental quality for overlapping generations: Some Reflections on the US Sky Trust Initiative. May 2005.

28. Thierry BRECHET, Benoît LUSSIS. The contribution of the Clean Development Mechanism to national climate policies. April 2005.

27. Thierry BRECHET, Stéphane LAMBRECHT, Fabien PRIEUR. Intergenerational transfers of pollution rights and growth. May 2005.

26. Maryse LABRIET, Richard LOULOU. From non-cooperative CO_2 abatement strategies to the optimal world cooperation: Results from the integrated MARKAL model. April 2005.

25. Marc GERMAIN, Vincent VAN STEENBERGHE, Alphonse MAGNUS. Optimal Policy with Tradable and Bankable Pollution Permits : Taking the Market Microstructure into Account.*Journal of Public Economy Theory*, 6(5), 2004, 737-757.

24. Marc GERMAIN, Stefano LOVO, Vincent VAN STEENBEGHE. De l'impact de la microstructure d'un marché de permis de polluer sur la politique environnementale. *Annales d'Economie et de Statistique*, n° 74 – 2004, 177-208..

23. Marc GERMAIN, Alphonse MAGNUS, Vincent VAN STEENBERGHE. Should developing countries participate in the Clean Development Mechanism under the Kyoto Protocol ? The low-hanging fruits and baseline issues. December 2004.

22. Thierry BRECHET et Paul-Marie BOULANGER. Le Mécanisme pour un Développement Propre, ou comment faire d'une pierre deux coups. *Regards Economiques*, Ires n° 27, janvier 2005.

21. Sergio CURRARINI & Henry TULKENS. Stable international agreements on transfrontier pollution with ratification constraints. In C. Carrarro and V. Fragnelli (eds.), *Game Practice and the Environment*. Cheltenham, Edward Elgar Publishing, 2004, 9-36. (also available as CORE Reprint 1715).

20. Agustin PEREZ-BARAHONA & Benteng ZOU. A comparative study of energy saving technical progress in a vintage capital model. December 2004.

19. Agustin PEREZ-BARAHONA & Benteng ZOU. Energy saving technological progress in a vintage capital model. December 2004.

18. Matthieu GLACHANT. Voluntary agreements under endogenous legislative threats and imperfect enforcement. November 2004.

17. Thierry BRECHET, Stéphane LAMBRECHT. Puzzling over sustainability: an equilibrium analysis. November 2004.

16. Vincent VAN STEENBERGHE. Core-stable and equitable allocations of greenhouse gas emission permits.. October 2004. (also available as CORE DP 2004/75)

15. Pierre-André JOUVET Philippe MICHEL, Pierre PESTIEAU. Public and private environmental spending. A political economy approach. September 2004. (also available as CORE DP 2004/68.)

14. Thierry BRECHET, Marc GERMAIN, Vincent VAN STEENBERGHE. The clean development mechanism under the Kyoto protocol and the 'low-hanging fruits' issue. July 2004. (also available as CORE DP 2004/81).

13. Thierry BRECHET, Philippe MICHEL. Environmental performance and equilibrium. July 2004. (also available as CORE DP 2004/72).

12. Luisito BERTINELLI, Eric STROBL. The Environmental Kuznets Curve semi-parametrically revisited. July 2004. (also available as CORE DP 2004/51).

11. Axel GOSSERIES, Vincent VAN STEENBERGHE. Pourquoi des marchés de permis de polluer ? Les enjeux économiques et éthiques de Kyoto. April 2004. (also available as IRES discussion paper n° 2004-21).

10. Vincent VAN STEENBERGHE. CO_2 Abatement costs and permits price : Exploring the impact of banking and the role of future commitments. December 2003. (also available as CORE DP 2003/98).

9. Katheline SCHUBERT. Eléments sur l'actualisation et l'environnement. March 2004.

8. Marc GERMAIN. Modélisations de marchés de permis de pollution. July 2003.

7. Marc GERMAIN. Le Mécanisme de Développement Propre : Impacts du principe d'additionalité et du choix de la baseline. January 2003.

6. Thierry BRECHET et Marc GERMAIN. Les affres de la modélisation. May 2002.

5. Marc GERMAIN and Vincent VAN STEENBERGHE. Constraining equitable allocations of tradable CO_2 emission quotas by acceptability, *Environmental and Resource Economics*, (26) 3, 2003.

4. Marc GERMAIN, Philippe TOINT, Henry TULKENS and Aart DE ZEEUW. Transfers to sustain dynamic core-theoretic cooperation in international stock pollutant control, *Journal of Economic Dynamics & Control*, (28) 1, 2003.

3. Thierry BRECHET, Marc GERMAIN et Philippe MONTFORT. Spécialisation internationale et partage de la charge en matière de réduction de la pollution. (also available as IRES discussion paper n°2003-19).

2. Olivier GODARD. Le risque climatique planétaire et la question de l'équité internationale dans l'attribution de quotas d'émission échangeable. May 2003.

1. Thierry BRECHET. Entreprise et environnement : des défis complémentaires ? March 2002.

Environmental Economics & Management Memorandum

Chair Lhoist Berghmans in Environmental Economics and Management
Center for Operations Research & Econometrics (CORE)
Université catholique de Louvain (UCL)
Voie du Roman Pays 34
B-1348 Louvain-la-Neuve, Belgium

Hard copies are available upon request : env@core.ucl.ac.be
Papers are available in pdf format on line : www.core.ucl.ac.be/chlhoist