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Financial Instruments for the Control of Transboundary Pollution

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Foreword

Initiatives to reduce emissions of acidifying air pollutants, such as the new 'sulfur protocol' currently discussed under the Convention on Long-range Transboundary Air Pollution are important steps to reduce acid deposition in Europe.

It is always useful, however, to examine whether further improvements in terms of environmental protection, or reduced pollution control costs, might not be possible. In this paper, Andries Nentjes analyzes the extent to which various, altruistic motives can influence the effect financial transfers have on the welfare gains of international agreements. Nentjes starts with a survey of the essential concepts of cooperative and non-cooperative Nash-Cournot equilibrium and market equilibrium in the context of two country models of reciprocal, transboundary pollution. Then he replaces the standard assumption that countries are only interested in their own costs and level of pollution by alternative assumptions that countries are also concerned with either the environmental quality or the level of pollution control costs in the other country. The results suggest that such international care can lead to a change in the usual reciprocal emission reduction commitments, without side-payments. It also affects the efficiency gains from joint implementation.

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Abstract

International agreements to protect the environment usually have the form of promises between countries to reduce pollution on a reciprocal base. Such a solution can be Pareto-efficient if transboundary pollution is reciprocal and, on top of that, negotiators reveal truly the preferences of their governments for environmental quality and the national costs of pollution control.

However, there are conditions under which the outcomes in terms of welfare gains can be improved by making payments between countries a part of the deal. The paper discusses the following categories:

(1) International money payment in exchange for additional pollution control abroad and simultaneous reduction of control effort at home as a complement to existing international agreements: Joint Implementation.

(2) Money transfers as an instrument to make an agreement on transboundary pollution feasible: control of unidirectional pollution and (ambitious) proportional reciprocal reduction of emissions belong to this class.

(3) International care. A country cares about the environment, or about the standard of living in another country. At first sight such considerations of international care seem to offer an argument for international subsidies. However, it will be shown that this is not necessarily so, since care considerations are already reflected in the 'rates of exchange' of the agreement to reduce emissions reciprocally.

Contents

1. Introduction

International agreements to protect the environment usually have the form of reciprocal promises between countries to reduce pollution. But how effective is this instrument in stopping ongoing environmental degradation and in improving environmental quality? Under which conditions should other instruments be brought in; in particular international money transfers? Should payments in money be applied as a supplement to trade 'in natura', like a reciprocal reduction of emissions, or can they be used as a superior alternative? These are the questions that will be dealt with in this paper. Answering them will also clear up a bit the mist that surrounds the concept of 'Joint Implementation'. Although not explicitly mentioned, the idea of Joint Implementation is implicitly part of the UN Montreal Protocol of September 1987 on substances that deplete the ozone layer.[1] This concept also pops up in the United Nations Framework Convention on Climate Change (May 1992). In order to curb emissions of greenhouse gases Parties to the Convention may implement their control policies and measures jointly with other Parties (Art. 4.2a). The Convention also defines 'a mechanism for the provision of financial resources on a grant or concessional basis' for the implementation of the convention (Art. 11.1 and 5).

Since the criteria for Joint Implementation still have to be worked out it is not so clear what Joint Implementation exactly is and how it will affect the behaviour of parties to international agreements. Since it is highly unlikely that one country would take over the obligations of other countries without some form of compensation one would expect that payments in money will be a part of Joint Implementation agreements.

A priori, a number of arguments can be given for money payments between countries as part of an international agreement to reduce transboundary pollution. The following ones and their consequences will be discussed.

(1) Cost-effectiveness. A chosen level of environmental quality in country D can be achieved by increasing the emissions in the donor country D and decreasing them in the receiving country R. Such a substitution of emissions (emission trading) is cost effective if emission reduction costs in R are lower than in D. Cost savings in D will exceed the payment it has to make in order to compensate country R for its (additional) abatement effort.

(2) Environmental effectiveness. This motive can operate if environmental quality in

country D can be improved by additional reduction of emissions in country R. One can imagine a situation where marginal costs of improving environmental quality in D exceed the perceived marginal benefits in D, whereas country R can do the job at marginal costs which are below D's marginal benefits. The money transfer paid by D to compensate R for its additional abatement costs can then be less than D's benefits of higher environmental quality.

These two arguments are well known. The 'added value' of this paper is a more precise delineation of the conditions under which money transfers have to be brought in to raise environmental and cost effectiveness and their relation with the concept of Joint Implementation.

Environmental and cost-effectiveness are relevant arguments for applying international payments if countries seek cooperation only for narrow selfish reasons. This holds true even if transboundary pollution is reciprocal and therefore reciprocal reduction of emissions is a feasible instrument in negotiations. The question is in how far these conclusions change if we bring in international altruism as a motive that affects the relations between nations and can play a role in international environmental negotiations.

In the economic theory of social policy the concept of specific care is used to explain public expenditure on such private goods as health care and housing. The relatively rich are assumed to care for poorer persons and in particular for their provision with specific goods like health care and housing. 'Specific care' is revealed in the willingness to pay for the 'poor' person's consumption of goods like health care and housing (Culyer, 1980).[2]

There also exists such a thing as international care. Development aid, for example, can be explained as evidence of the economically developed countries' care for the low living standards in the underdeveloped world. It can also be observed that people in one country care for the environment in other countries. This brings us to the third and fourth motive for international environmental cooperation and possibly international subsidies.

(3) Environmental care. With regard to Eastern Europe there seems to exist (specific) environmental care in the Western world. Governments of countries in the West might be willing to pay for reducing environmental burdens in Eastern Europe. Not for the reason that the West will benefit directly in the form of better environmental quality in the West, but because of the environmental improvement in the East. Such environmental improvements give indirect benefits to the West. These can be of two

kinds. If lower levels of pollution contribute to the preservation and restoration of natural areas and of cultural heritage in a country people from other countries also can enjoy this beauty as tourists or by way of the media. The benefits arising from this type of consumption can hardly be called altruistic. Altruistic benefits are for example those that arise from the knowledge that health and other elements of the quality of life in other countries improve.

In this paper we shall take these two motives for environmental care together. Their nature and origin may be different but both imply that in the view of the West the former communist states undervalue their environment. Left to themselves this would lead to 'underconsumption' of environmental quality. To prevent environmental damage Western countries might support the countries about which they care with financial aid, earmarked to be used for reduction of their internal pollution load. The intention of such a transfer would be additional improvement of environmental quality in the receiving country only.

(4) Economic care. Former communist countries are in the process of restructuring their economies. The readjustments inflict heavy economic and social pains upon the people. At the same time environmental policies have to be developed. Pollution abatement costs are an additional financial burden for firms which have already a difficult time. Specific economic care in the West would mean that Western countries are willing to pay for the economic development which will raise the standards of living in the restructuring countries. In the context of environmental policy it implies that country D is willing to provide subsidies that would help country R to reduce the financial burden imposed by the costs of emission reductions. Such a subsidy has a close analogy on the national level in the environmental subsidies that were given in the West during the seventies. The bulk of the national subsidies had not the function to induce additional pollution abatement effort, but instead was given to support firms in their adjustment from the old regime without environmental standards to a new regime with the additional cost of imposed environmental measures. Specific international economic care might result in an international subsidy flow to ease the transition of firms in Eastern Europe which have to face a double adjustment: to a market regime and an environmental policy regime as well. The consequences of international environmental and economic care are analyzed in Section 4.

(5) Next to these four motives international transfers can be used as a means to facilitate

the unanimous acceptance of proposals for proportional emission reduction, or proportional reduction of pollution loads. This is analyzed in Section 3.4. Intra- and transboundary benefits of uniform emission reduction differ largely between countries. The result can be that for some countries the total benefits from the proposed programme exceed abatement costs, whereas other countries, especially those with large pollution 'export' and low pollution 'import', will run into net negative benefits. The prospect of net negative benefits will block the acceptance of the uniform reduction proposal. A money transfer from the countries that gain from the proposed agreement to those that fear to loose can be necessary to get their cooperation.

The arguments in defense of international environmental transfers will be subjected to a more precise analysis in the following sections. The main questions to be answered are:
(1) Under which conditions is each of the arguments valid; in other words what exactly are the underlying assumptions?
(2) Is the transfer a supplement to international agreements to reduce pollution reciprocally, or is it a substitute for reciprocal reduction?

In the present literature these questions have not been discussed explicitly. Of course there is the notion that side payments usually are a condition for cost efficiency of international agreements on pollution reduction. Most authors, like Mäler (1989, 1990), Tulkens (1991), Welsch (1993), take a non-cooperative equilibrium as a starting point and compare it with a Pareto optimal solution which can be attained if side payments are allowed. In his analysis of a global pollutant Hoel (1991) refines the conceptual framework by making a distinction between Pareto efficiency with side payments and efficiency without side payments, but he does not analyze the implications of this distinction. As will be shown in Section 2 the distinctions between non-cooperative equilibrium, Pareto efficiency without side payments and Pareto efficiency with side payments (or joint equilibrium) play a crucial role in giving the concept of Joint Implementation its proper place in theory. The role of international care in international environmental agreements and its impact on the outcomes has not been researched at all.

The organization of the paper is as follows. Section 2 gives a survey of the essential concepts and analyses the scope for Joint Implementation in the case of reciprocal transboundary pollution. Section 3 discusses the function of money transfers in some special cases; the most interesting is the case of uniform reductions of emissions or pollution loads.

The role of international care in environmental agreements is analyzed in Section 4. Conclusions are given in Section 5.

2. Reciprocal reduction of emissions

The analysis takes as its starting point two countries. Environmental quality in each country is affected by its own emissions and (for at least one of the countries) also by the emissions of the other country. Decisions on environmental policy are made by the national governments. The perceptions and valuations of the environmental problem are caught in a simple separable utility function $W_i = B_i(r_i) - C_i(z_i)$, with $i = 1,2$.[3] For country 1 B_1 represents the benefits from reducing the pollution load (r_1) and C_1 the costs of emission reduction (z_1). The concept of environmental benefits does not necessarily imply that benefits can be measured accurately and 'translated' into monetary terms. What is meant here is benefits in a subjective sense, it is assumed that the political body has a certain willingness to pay for environmental improvement. Environmental benefit and cost functions are twice differentiable with decreasing marginal benefits and increasing marginal costs. Emission reduction and decrease of pollution loads are connected by the transmission relations $r_1 = r_1(z_1,z_2)$ and $r_2 = r_2(z_1,z_2)$, which are specified in a linear form. $z_1 = a_{11}z_1 + a_{12}z_2$ and $z_2 = a_{21}z_1 + a_{22}z_2$.

The utility function $W_i = B_i(r_i) - C_i(z_i)$ implies that national governments are only interested in benefits and costs at home and not in the benefits and costs of other countries. The governments pursue the national interest as they see it. In the economic approach such behaviour is described by maximizing the governments utility function under the constraint of the relevant transmission equation(s).

2.1 Non-cooperative Nash equilibrium

When there is no cooperation between governments, and each government considers the level of emission and emission reduction of its neighbour as given, the condition for the non-cooperative Nash equilibrium is derived by maximizing the Lagrange functions

$$L_1 = B_1(r_1) - C_1(z_1) + \lambda_1(r_1 - a_{11}z_1 - a_{12}z_2) \quad (1)$$

$$L_2 = B_2(r_2) - C_2(z_2) + \lambda_2(r_2 - a_{21}z_1 - a_{22}z_2) \quad (2)$$

The first order conditions are

$$C_1' = a_{11}B_1' \quad (3)$$

$$C_2' = a_{22}B_2' \quad (4)$$

Equations (3) and (4) tell that both countries control their emission up to the point where marginal cost are equal to the marginal internal, or national environmental benefits. The equations are both functions in z_1, z_2 the so-called reaction functions. By substituting the transmission functions in the first order conditions and taking the total differential the sign and magnitude of the reaction coefficients can be found.

For country 1

$$\frac{dz_1}{dz_2} = \frac{-a_{12}}{a_{11} - (C_1'' / a_{11}B_1'')}, where\ -1 < \frac{dz_1}{dz_2} < 0 \quad (5)$$

For country 2

$$\frac{dz_2}{dz_1} = \frac{-a_{21}}{a_{22} - (C_2'' / a_{22}B_2'')}, where\ -1 < \frac{dz_2}{dz_1} < 0 \quad (6)$$

(5) and (6) show that in case country 2 increases its emission reduction, country 1 will react by reducing its abatement effort (and increasing emissions). The reaction curve of country 1 is represented by curve R_1 in Figure 1; R_2 is the reaction curve of country 2. The negative reaction will be stronger the higher the pollution import coefficient is (a_{12} for country 1) and the sharper the increase of marginal abatement costs is relative to the decline in marginal benefits. The non cooperative Nash equilibrium is represented by point N; the intersection of the two reaction curves, in figure 1. In this paper point N will be taken as a reference point. We take for granted that if countries do not cooperate in their control of transboundary emissions the resulting situation can be identified as the Nash equilibrium N.

2.2 Cooperative Nash equilibrium

Both countries can improve their welfare by cooperation: that is, coordination of their pollution control policies. Country 1 can offer to raise its reduction of emissions on the condition that country 2 follows the same line of action. The effect will be that country 1 gets more reduction of pollution load in return for an extra unit of emission reduction than it would have got under the non cooperative policy regime. The same holds true for country 2. So there is room to contract a reciprocal increase of emission reduction from which both countries will derive net benefits.

This is shown in Figure 2. $\bar{W}_1$ is the iso-welfare curve or iso-net benefit curve of country 1. To the right of point N the $\bar{W}_1$ curve is increasing: any increase in z_1 increases pollution control costs; in order to raise environmental benefits in such a way that net benefits in country 1 remain constant country 2 would have to increase its level of pollution control as well. Increasing marginal costs in country 1 make that country 2 would have to raise z_2 increasingly in order to provide the necessary additional environmental benefits. To the left of N net environmental benefits of country 1 are decreased by decreasing z_1 because the loss of environmental benefits exceeds the savings on pollution control costs. In order to keep $\bar{W}_1$ constant country 2 has to increase its level of pollution control. It should be noted that any point in the area above $\bar{W}_1$ constitutes higher welfare for country 1 than points on the iso welfare curve and therefore is preferred to points on $\bar{W}_1$.

Figure 2 also shows the iso-welfare curve $\bar{W}_2$ for country 2. Points to the right of $\bar{W}_2$ are preferred to points on the curve. The contract area, enclosed by curves $\bar{W}_1$ and $\bar{W}_2$, is the set of all possible combinations of z_1,z_2 with higher welfare for at least one country and welfare higher than or equal to welfare in N for the other country.

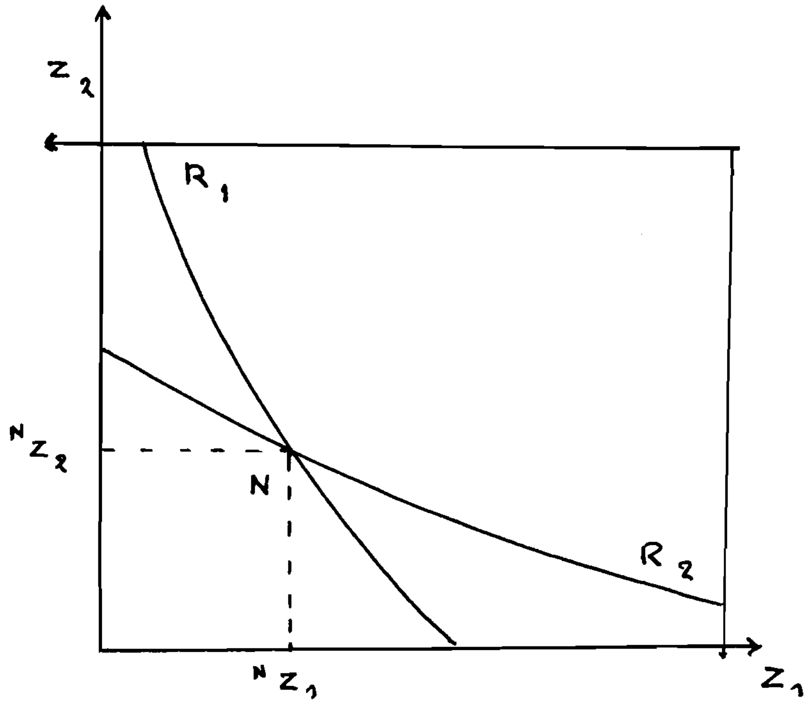


Figure 1

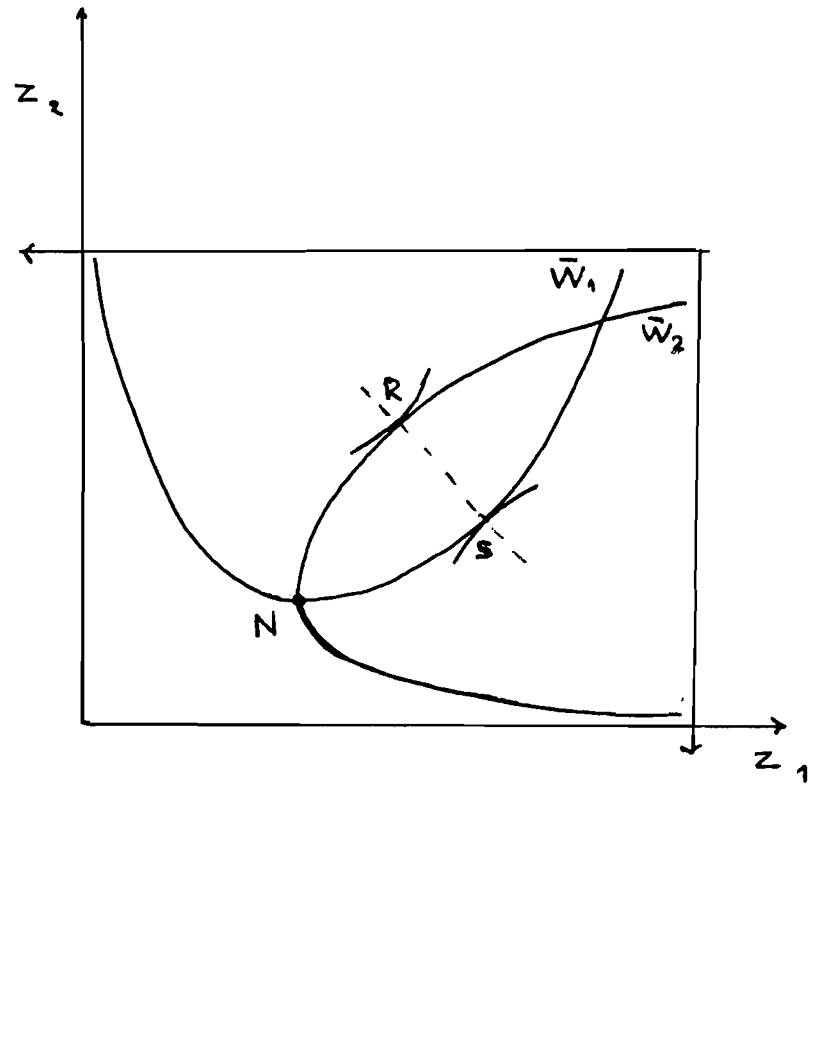


Figure 2

The first order condition for a Pareto-optimum is derived by maximizing the Lagrange function

$$L = B_1(r_1) - C_1(z_1) + \lambda_1(r_1-a_{11}z_1-a_{12}z_2) + \mu_1[(\bar{W}_2 - B_2(r_2) + C_2(z_2)] + \lambda_1(r_2-a_2z_1-a_{22}z_2). \quad (7)$$

The first order conditions are

$$C_1' = a_{11}B_1' - \mu_1 a_{21}B_2' \quad (8)$$

$$C_2' = a_{22}B_2' - 1/\mu_1 a_{12}B_1' \quad (9)$$

Equations (8) and (9) state that for a Pareto optimum the transboundary benefits of pollution control have to be taken into account next to the national or internal benefits. The Lagrange multiplicator is $-\mu_1 > 0$; this implies that in the Pareto optimum C_1', C_2' will be larger than in the non cooperative Nash equilibrium and consequently z_1, z_2.[4]
The first order conditions can be reduced to the equation[5]

$$\frac{C_1' - a_{11}B_1'}{a_{12}B_1'} = \frac{a_{21}B_2'}{C_2' - a_{22}B_2'} \quad (10)$$

The first order condition (10) is an equation with two variables z_1, z_2. The equation represents the Pareto optimum, depicted in Figure 2 by the contract curve RS, bounded by the restrictions $W_1 \geq \bar{W}_1$, $W_2 \geq \bar{W}_2$, where $\bar{W}_1$ and $\bar{W}_2$ are the net benefits in the non-cooperative Nash equilibrium. If no money payments are involved and negotiations concentrate on reciprocal reduction of emissions the cooperative Nash equilibrium is a point on the contract-curve of Pareto-efficient solutions.

2.3 Market equilibrium

To define a reference point on the contract curve we introduce the concept market equilibrium of reciprocal emission reduction.[6] When two countries 1 and 2 negotiate on the size of their mutual emission reduction z_1 and z_2, the ratio z_1/z_2 constitutes the rate of exchange or price of the 'goods' that are traded. A market equilibrium, comparable with market equilibrium under perfect competition, could be established if the negotiating parties would take the price ratio (z_1/z_2 or z_2/z_1) as given.

One can imagine that parties agree to appoint an auctioneer who announces successive price ratios to which each party will respond by making its corresponding emission reduction offer. This offer is the result of maximization of net benefits under the constraint of a given price ratio. Figure 3 illustrates how the offer curve for country 1 is derived as a series of points of tangency of successive price lines and iso-welfare curves. In the same way the offer curve for country 2 can be derived. By calling prices in successive rounds the offer curves are identified and the market equilibrium can be discovered by the tâtonnement procedure. If the emission reduction offers z_1^S, z_2^S are such that their ratio z_1^S/z_2^S equals the given price ratio z_1/z_2 the market equilibrium is attained.

The behaviour of countries 1 and 2 under the market regime is modeled by maximization of the following Lagrange functions for each country.

$$L_1 = B_1(r_1) - C_1(z_1) + \lambda_1(r_1 - a_{11}z_1 - a_{12}\pi_1 z_1) \tag{11}$$

$$L_2 = B_2(r_2) - C_2(z_2) + \lambda_2(r_2 - a_{21}\pi_2 z_2 - a_{22}z_2) \tag{12}$$

π_1 is the price ratio z_2/z_1 and π_2 $(=1/\pi_1)$ the price ratio z_1/z_2. The constraint $r_1 - (a_{11}+a_{12}\pi_1)z_1$ says that in deciding on its emission reduction country 1 does not only take into account the direct impact on the pollution load at home (that is $a_{11}z_1$) but also the indirect impact, since country 2 responds by offering z_2 at a given ratio π_1, which reduces the pollution load in country 1 with $a_{12}\pi_1 z_1$ $(=a_{12}z_2)$. The same type of argument holds for country 2.

The first order conditions are

$$C_1' = (a_{11}+a_{12}\pi_1)B_1' \tag{13}$$

$$C_2' = (a_{22}+a_{21}\pi_2)B_2' \tag{14}$$

Equation (13) and (14) are functions in z_1, z_2. They can be interpreted as offer curves. The offer curves and their point of intersection, that is the market equilibrium M, are shown in Figure 4.

From (13) and (14) follows the equilibrium ratio

$$\frac{z_2}{z_1} = \pi_1 = \frac{C_1' - a_{11}B_1'}{a_{12}B_1'} = \frac{1}{\pi_2} = \frac{a_{21}B_2'}{C_2' - a_{22}B_2'} \tag{15}$$

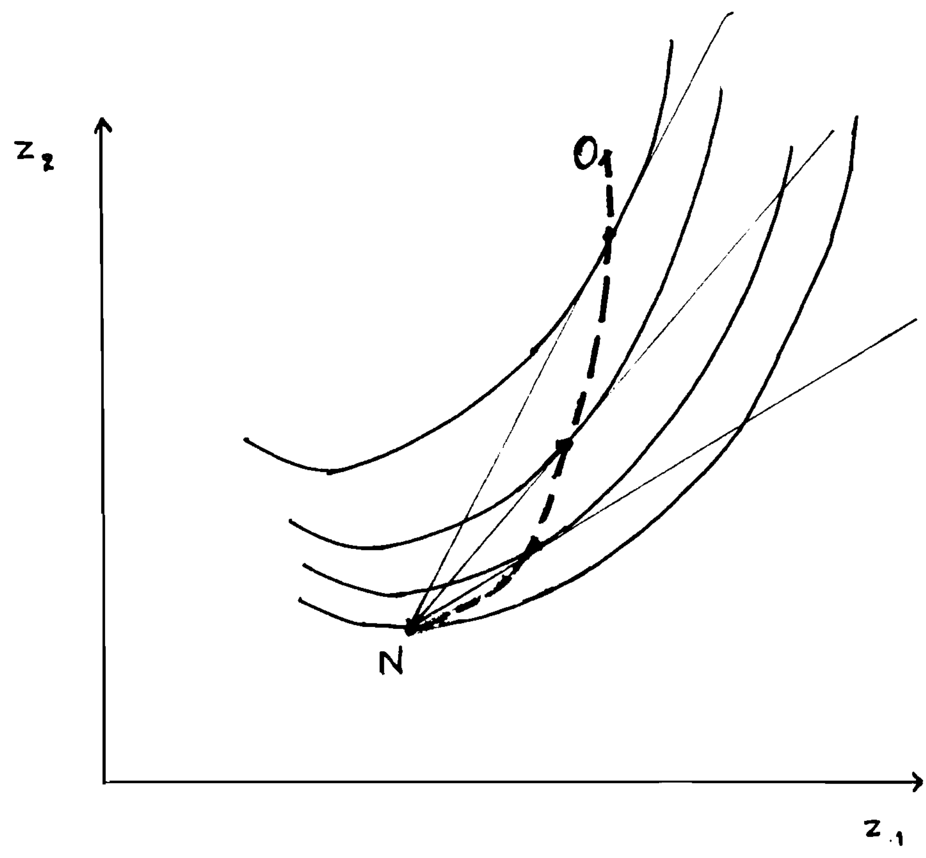


Figure 3

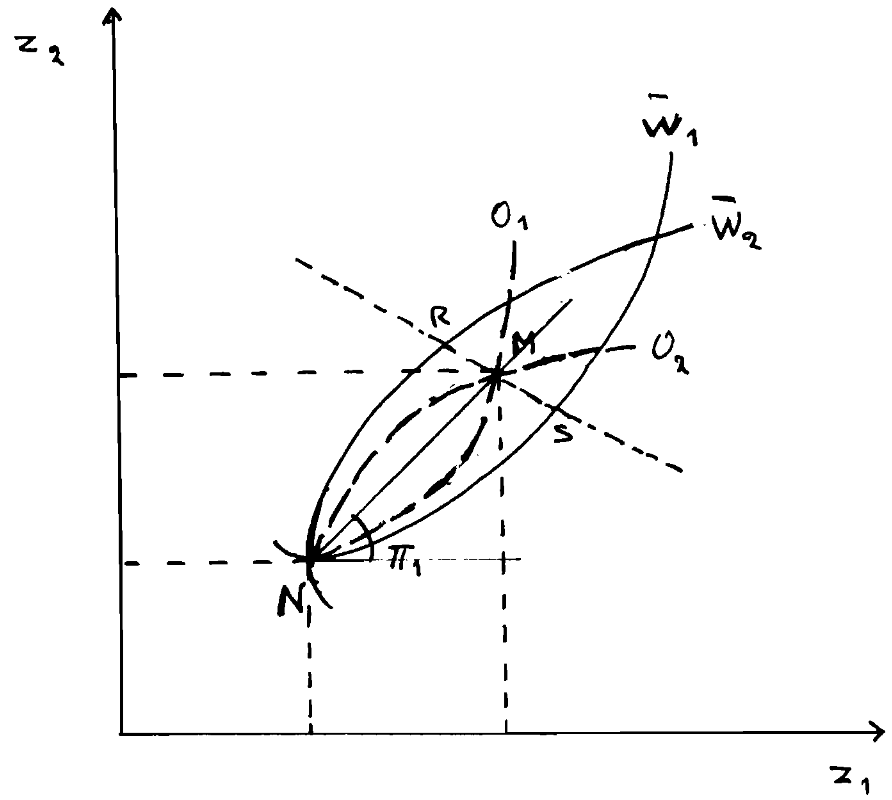


Figure 4

A comparison with (10) reveals that the market equilibrium satisfies the conditions for a Pareto-equilibrium of reciprocal reduction of pollution. Equation (15) also shows that a finite price > 0 is possible only if transboundary pollution is reciprocal (a_{21} and $a_{12} > 0$), if there are (politically perceived) positive marginal environmental benefits in both countries, and abatement technologies are available at finite marginal costs. The reciprocal transboundary pollution may be very asymmetric, this does not prevent that a deal with a finite rate of exchange can be struck. The 'terms of trade' z_2/z_1 will be unfavourable to country 1 if its marginal benefits from a lower pollution load are high, in particular in combination with a high pollution import and a low pollution export coefficient and if its marginal cost are low. In such a case the exchange rate may seem very unfavourable to country 1, but it should not be forgotten that in this example country 1 has also the largest benefits from cooperation. Actually, the 'market price' tends to reduce potential inequalities in the distribution of net welfare benefits between the countries. In the example given above country 1 would potentially reap the largest benefits, but this is moderated by its relatively unfavourable rate of exchange. For country 2 the opposite holds true.

When two countries negotiate the introduction of an auctioneer might be a feasible option, since in bilateral negotiations on emission reduction free riding is not possible. In the case of more than two parties the problem arises that negotiators have an incentive not to reveal their true preference in their emission reduction offers. For example country 2 could understate its willingness to abate, hoping that it will benefit for free from the abatement efforts made by other parties. The public good property of abatement of transboundary pollution limits the usefulness of applying the auctioneering procedure in the real world.[7] The concept of market equilibrium is used in this paper for analytical purposes only. Its analytical usefulness is that it gives determinateness to the outcomes of negotiations which otherwise would be largely indeterminate. In this paper the main function of the market solution of reciprocal reductions is that it provides a point of reference on the contract curve, in particular for comparison with the point of maximum joint welfare.

3. Joint Implementation

The Pareto efficiency condition (10) is derived for a situation where welfare of countries can only be increased by exchanging reduction of emissions. The scope for Pareto-efficient outcomes could be increased even more if international money is added as a means of exchange between the two countries. The variables Y_1, Y_2 are added to the welfare functions. Total revenue is constrained in the sense that $+Y_1 = -Y_2$: revenue for country 1 is expenditure for country 2 and vice verse. Adding real income, expressed in international money units, to B_i and C_i implies that these two are expressed in these units. The introduction of international money makes it feasible to compensate a country which increases its pollution control, which will decrease its net environmental benefits, by increasing its real income. In the other country real income is reduced, but this can be compensated by higher transboundary environmental benefits and lower net costs of pollution control, brought about by lowering its abatement.

The first order conditions for the Pareto optimum with payments are derived by maximizing the Lagrange function

$$L = B_1(r_1) - C_1(z_1) + Y_1 + \mu_1\{\bar{W}_2 - B_2(r_2) + C_2(z_2) - Y_2\} + \lambda_1(r_1 - a_{11}z_1 - a_{12}z_2) + \lambda_2(r_2 - a_{21}z_1 - a_{22}z_2) + \delta(Y_1 + Y_2) \quad (16)$$

First order conditions are

$$C_1' = a_{11}B_1' + a_{21}B_2' \text{ or } C_1' - a_{11}B_1' = a_{21}B_2' \quad (17)$$

$$C_2' = a_{21}B_1' + a_{22}B_2' \text{ or } C_2' - a_{22}B_2' = a_{12}B_1' \quad (18)$$

From equations (17) and (18) the two unknown variables z_1, z_2 can be solved. They are a special case of (8) and (9), with $-\mu_1 = 1$. In other words, the Pareto optimum with money transfers must be a point on the Pareto optimum curve with emission reductions as the only action variables. Therefore finding the Pareto optimum with money payments can be interpreted as a movement along the z_1, z_2 Pareto optimum curve through R and S in figure 2.

Welfare of both countries is interpreted as the sum of net willingness to pay for a clean environment plus real income. Starting from any point on the curve RS, it is possible to assess whether a movement along that curve, which changes the combination (z_1, z_2) (and (r_1, r_2) as well) increases welfare of, say, government 1 by more or by less than it decreases welfare of country 2. If the 'winner' can and does compensate the 'loser' fully in the form of a money transfer both parties can agree on the move along the contract curve. In this way the Pareto optimum with money transfers can be found in principle. Now that international money is involved it cannot be excluded that the Pareto optimum is a point beyond the disagreement point R or S on the curve through R and S in figure 2: a country, whose welfare is in danger to be reduced below the welfare of the Nash non cooperative equilibrium, can be compensated in money.

An omniscient planner could try to realize the Pareto optimum with money transfer by imposing the optimal z_1, z_2 plus compensating payments on parties. Here it will be shown that a solution which satisfies conditions (17) and (18) can be found through negotiations. The crucial difference is that the introduction of money makes it feasible to split up the negotiations on z_1, z_2 into separate decisions on z_1, respectively z_2. One can imagine an auctioneer who operates on and coordinates two 'markets': for z_1 the price is t_1 and for z_2 the price t_2. The rule of the game is that at the announced price t_1 country 1 reports how many units of z_1 it is willing to offer, or to withdraw from the market compared with the initial situation; country 2 mentions how many units z_1 it demands, because of the transboundary environmental benefits they create. The demand of country 2 can be positive or negative. Mutatis mutandis the supply and demand of z_2 are discovered in the same way. Formally the problem is solved as follows. Let T_1 be the transfer received by country 1 with $T_1 = t_1 z_1$, where t_1 is the transfer received per unit of emission reduction. $T_2 = t_2 z_2$ is the transfer paid by country 1 and received by country 2. Both countries maximize their welfare, including net transfers. Maximization of the Lagrange equations[8]

$$L_1 = B_1(r_1) - C_1(z_1) + t_1 z_1 - t_2 z_2 + \lambda_1(r_1 - a_{11} z_1 - a_{12} z_2) \tag{19}$$

$$L_2 = B_2(r_2) - C_2(z_2) + t_1 z_1 - t_2 z_2 + \lambda_2(r_1 - a_{21} z_1 - a_{22} z_2) \tag{20}$$

gives the first order conditions

$$a_{11} B_1' - C_1' = t_1 \tag{21}$$

$$a_{12} B_1' = t_2 \tag{22}$$

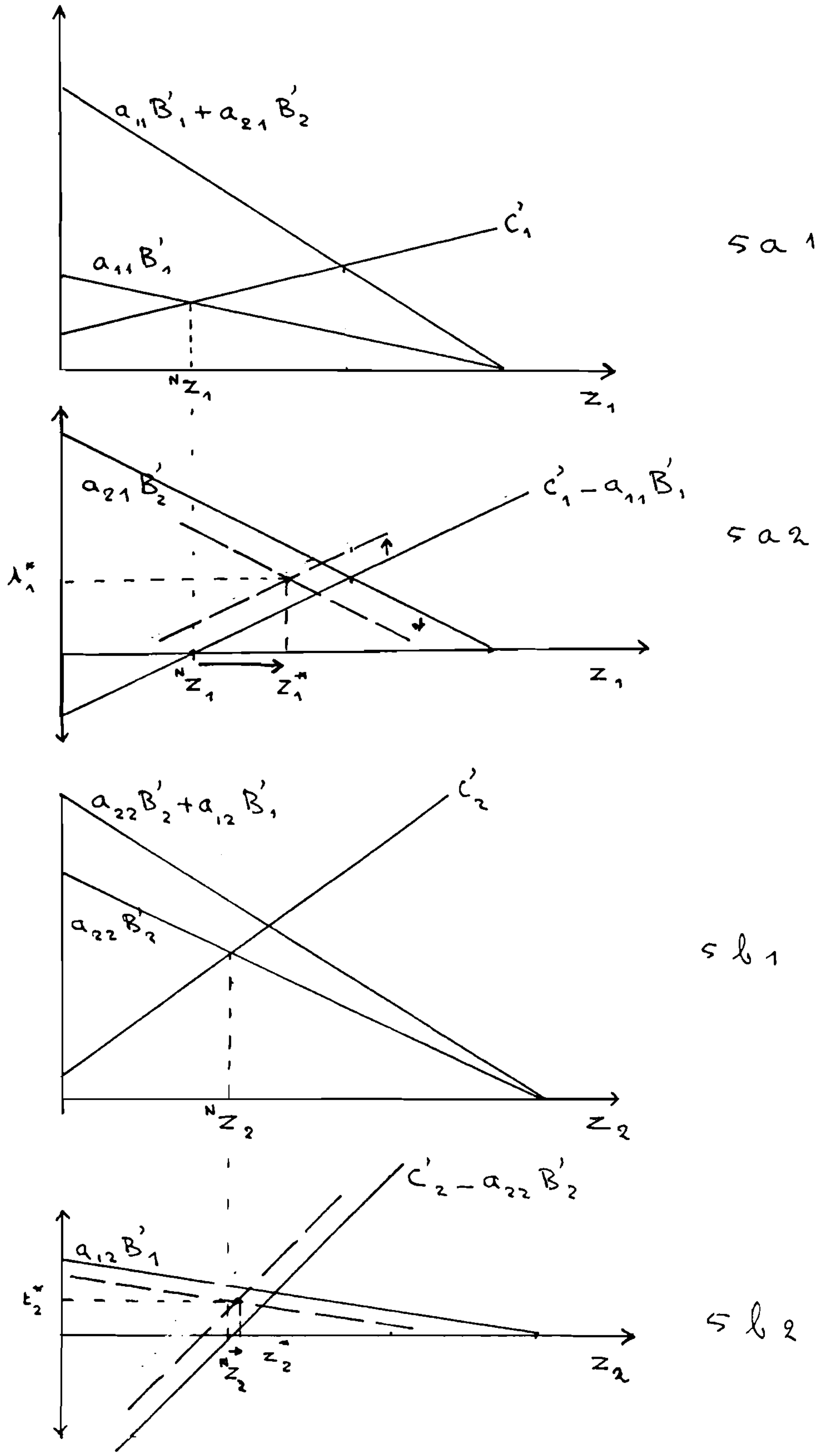
$$a_{22} B_2' - C_2' = t_2 \tag{23}$$

$$a_{21} B_2' = t_1 \tag{24}$$

From the four equations that define the market equilibrium the four unknown values t_1, t_2, z_1 and z_2 can be solved. The conditions for a market equilibrium with money payments also satisfy the condition for a Pareto optimum with money payments. This can be verified by substituting (24) in (21) and (22) in (23).

It is instructive to discuss more in depth the process of tâtonnement that could lead up to the Pareto optimum. Much depends from where negotiations with money payments start. We shall discuss two possibilities. The first one is that money is used starting from the Nash non-cooperative equilibrium. In N both parties disregarded the transboundary environmental benefits of their pollution control. The positive prices t_1,t_2 signal the willingness to pay for additional emission reduction to suppliers of pollution control and simultaneously the willingness to supply to demanders.

Equation (21) defines the supply of z_1 for any given value of t_1 and z_2, and (24) the demand function for z_1, with t_1 and z_2 given. (22) and (23) represent the demand, respectively supply of z_2, with t_2 and z_1 given. At the start the given values of ${}^Nz_2$ and ${}^Nz_1$ are the non-cooperative Nash levels. The corresponding demand and supply curves for transboundary pollution control have been drawn in Figure 5a1 and 5b1. Starting from prices t_1,t_2 somewhat above zero, or by basing initial prices on his suppositions about marginal costs at ${}^Nz_1$, respectively ${}^Nz_2$, the auctioneer can use the information on excess demand to revise the values of z_1,t_1 and z_2,t_2 upwards for the second round. It should be noted that any increase in z_2 shifts the partial demand curve of country 2 for z_1 downwards, since a higher z_2 reduces the marginal benefits of reducing the pollution load by way of increasing z_1. This is shown in Figure 5a2. The supply curve of z_1 will shift upward: lower marginal environmental benefits for country 1, in consequence of the rise in z_2, will increase the net marginal costs of supplying z_1, (see Figure 5a2). The same kind of reasoning applies to the demand for and supply of country 2's pollution control, as pictured in Figures 5b1 and 5b2. Gradual adjustment of prices and quantities steered by the excess demands for z_1 and z_2 can make that the process of tâtonnement converging to an equilibrium. In Figure 5 the demand and supply curves in market equilibrium are represented by the dotted lines; z_1^*,z_2^*, t_1^* and t_2^* are the market equilibrium values.



$a_{11}B'_1 + a_{21}B'_2$
C'_1
$a_{11}B'_1$
$^N Z_1$
Z_1
5a1
$a_{21}B'_2$
$C'_1 - a_{11}B'_1$
λ_1^*
$^N Z_1$
Z_1^*
Z_1
5a2
$a_{22}B'_2 + a_{12}B'_1$
C'_2
$a_{22}B'_2$
$^N Z_2$
Z_2
5b1
$C'_2 - a_{22}B'_2$
$a_{12}B'_1$
t_2^*
$^N Z_2$
Z_2^*
Z_2
5b2

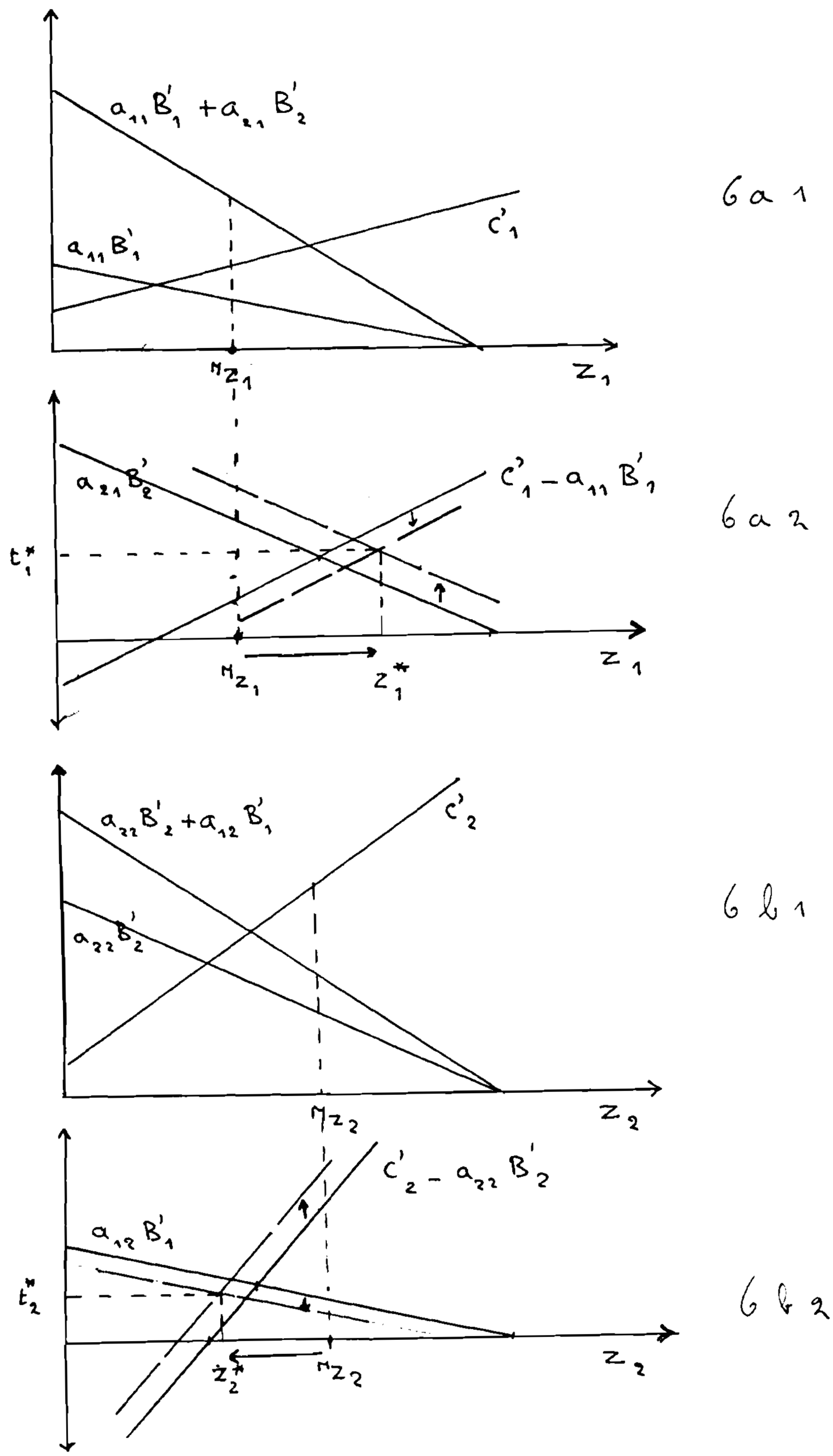
Figure 5

If the Nash non-cooperative equilibrium is the starting point for negotiations both countries will react to positive prices by increasing their supply of z_1 and z_2. The implicit (positive) exchange ratio between z_1 and z_2 in the market equilibrium with money is given by

$$\frac{z_2}{z_1}=\pi_1=\frac{1}{\pi_2}=\frac{a_{21}B_2'}{a_{12}B_1'}=\frac{C_1'-a_{11}B_1'}{C_2'-a_{22}B_2'} \tag{25}$$

The process of adjustment would take a somewhat different course if countries first negotiate on reciprocal reduction of emission which leads up to a point on the contract curve, for example the market equilibrium of reciprocal emission reduction, and subsequently take this agreement as a starting point for a second stage in which the first outcome is corrected by renegotiation on the allocation of pollution control with money payments. The cooperative equilibrium of reciprocal emission reduction is given by the Pareto efficiency conditions (10), or more specifically by market equilibrium equation 15). From both equations it follows that in market equilibrium of reciprocal reductions it is possible that we have $a_{21}B_2' > C_1'-a_{11}B_1'$, but then simultaneously it must be true that $C_2'-a_{22}B_2' > a_{12}B_1'$. In words: it could be that the marginal transboundary environmental benefits for country 2 of increasing pollution control in country 1 are larger than the marginal net costs of doing so in country 1. At the same time the net cost savings country 2 would get from decreasing its pollution control are higher than the loss of marginal transboundary benefits in country 1.

The process of adjustment is shown in Figure 6a and 6b. Starting from the given level ${}^{M}z_2$ a positive price t_1 based on marginal cost at ${}^{M}z_1$ would signal an excess demand for z_1 and accordingly z_1 would have to be raised. On the other hand an announced price t_2 based on marginal cost at ${}^{M}z_2$ (and $z_1 = {}^{M}z_1$) will reveal an excess supply of z_2, which indicates that a reduction of z_2 is in place. The successive reductions of z_2 raise the demand curve for z_1 and lower the supply curve. The increase of z_1 has the opposite effect on demand and supply of z_1. The market equilibrium with money payment is pictured in Figure 6 by the intersection of the dotted curves. The outcome of the adjustment process is that z_1 is increased and z_2 decreased compared with the initial allocation.



a11 B'1 + a21 B'2
C'1
a11 B'1
Mz1
z1
a21 B'2
C'1 − a11 B'1
t*1
Mz1
z*1
z1
a22 B'2 + a12 B'1
C'2
a22 B'2
Mz2
z2
C'2 − a22 B'2
a12 B'1
t*2
z*2
Mz2
z2
6a1
6a2
6b1
6b2

Figure 6

The additional supply of z_1 makes that country 2 has to pay to country 1 the sum t_1z_1 to compensate country 1 for its extra net costs of pollution control. The reduction of z_2 obliges country 2 to pay an additional sum of t_2z_2 to country 1 to compensate it for the reduction of its transboundary environmental benefits. One possible interpretation of the exchange is to see country 1 as offering a package of increasing z_1 with simultaneous reduction of z_2 in exchange for money. The net revenue for country 1 $T = t_1z_1-t_2z_2$ then can be reformulated as $T = (t_1+t_2|\pi_1|)z_1$ when $|\pi_1|$ is the absolute value of the negative valued exchange ratio z_2/z_1. By substituting (22) to (24) into the above equation it can be written in the form

$$T = \{(C_1'-a_{11}B_1')+a_{12}B_1'|\pi_1|\}z_1 \tag{26}$$

and for country 2

$$T = \{a_{21}B_2'\pi_2-(C_2'-a_{22}B_2')\}z_2 \tag{27}$$

The intuitive explanation for welfare improvement by starting from the market solution of reciprocal emission reduction and allowing money payments is as follows. Imagine a situation where in consequence of negotiations on reciprocal reduction of emissions country 1 has raised its pollution control compared with the Nash level of z_1. It has done so in response to country 2's offer to increase z. However, country 2's offer is constrained by its high marginal cost of reducing emissions. Although there are potential benefits to be reaped for country 2 if country 1 would increase its pollution control even more, country 2 can not afford to offer additional z_2 in return because this would raise net marginal costs for country 2 by more than its marginal benefit. However, if there exists a means of payment accepted by both countries then country 2 could pay country 1 in money for increasing its level of abatement. Since $a_{21}B_2' > C_1' - a_{11}B_1'$. Simultaneously country 2 could reduce its own level of emission control and save costs and set money free for compensating country 1 for both its net marginal cost of increasing z_1 and for its loss of transboundary marginal benefits arising from country 2's decrease of pollution control. This is possible since $C_2'-a_{21}B_2' > a_{12}B_1'$.

The upshot is that in the case of divergence between the market solution of reciprocal emission reduction and the joint welfare maximum both countries can improve their welfare by applying payments in money as an instrument complementary to the instrument of reciprocal reduction of emissions.

In the real world agreements on reduction of transboundary pollution usually fix the size of reduction in emissions for each participant in the agreement. The above analysis makes clear that, even if by introducing a kind of market system a Pareto optimal solution would have been realized, such optimal contracts in terms of reciprocal reductions leaves scope for additional gains in net benefits for parties in the agreement. Additional welfare gains could be realized if the contract leaves parties the flexibility to exchange obligations to reduce emissions in return for payment in money. Cost effectiveness as well as environmental effectiveness are served by this correction of the terms of the contract. Joint Implementation clauses in recent international conventions on Climate Change and reduction of CFC's seem to indicate that policy makers are beginning to discover the limitation of reciprocal reductions and the possibility of welfare gains by reallocating pollution control among countries in exchange for payment in money.

4. The argument for international transfers

In Section 3 one major argument for the introduction of money payments in international negotiations on reduction of transfrontier pollution was advanced. Such payments offer scope for outcomes with higher net benefits (higher environmental benefits and lower costs of pollution control) for parties than is feasible if negotiations are conducted solely in terms of reciprocal reduction of pollution. It has been shown that the instrument of money payments for reduction of transboundary pollution can be applied as a complement to outcomes that result from negotiations on reciprocal reduction of emissions (Joint Implementation), but also could be used as an alternative.

In this section three specific cases will be discussed where application of international compensations or subsidies might be in place. These are:

- unidirectional pollution,
- efforts to improve cost-effectiveness of international pollution control,
- uniform or equiproportional reduction of emissions or pollution loads.

In Section 5 two cases will be analyzed which differ from the cases in the earlier sections in that a country is interested not only in its own costs and benefits of pollution control but also in the environmental quality, or the costs of pollution control in other countries.

4.1 Unidirectional transboundary pollution

The analysis in Section 2 suggests that international money transfers are in place if transboundary pollution is unidirectional. Let country 1 be an 'exporter' of pollutants ($a_{21} > 0$) and consequently country 2 be the importer; but there is no transmission of pollutants from 2 to 1, i.e. $a_{12} = 0$; a_{11} and a_{22} both > 0. In this case the rate of exchange in the market solution based on reciprocal reduction $\pi_1 = (C_1' - a_{11}B_1')/0$ (see 2.10) would be undefined.[9] From the condition for a Pareto optimum of reciprocal emission reductions (10) it also shows that there exists no opportunity to improve welfare compared to the non-cooperative Nash equilibrium by reshuffling z_1 and z_2. There is no scope for improvement of welfare through 'trade' in terms of reciprocal reduction of emissions.

The use of a money transfer between 1 and 2 can solve the dilemma. If $a_{12} = 0$ and all other transmission coefficients > 0 the solution of the model with money payments between countries, that is equations (21) to (24), becomes, after substituting $a_{12} = 0$

$$C_1' - a_{11}B_1' = a_{21}B_2' = t_1 \tag{28}$$

$$C_2' = a_{22}B_2' \tag{29}$$

The pollution importing country 2 sticks to the emission reduction level at the former non-cooperative Nash equilibrium and it pays country 1 a financial transfer $T_1 = t_1z_1$, which is just high enough to make country 1 increase its abatement up to the level where the net marginal cost to 1 (C_1'-$a_{11}B_1'$) equals the marginal environmental benefits of 2 ($A_{21}B_2'$).

The international money transfer from the country that benefits is made for selfish reasons, i.e. the environmental effectiveness motive applies. It appears that environmental effectiveness is a valid argument for international environmental money transfers if transboundary pollution is unidirectional.[10]

A case can be made for international transfer from Western Europe to Eastern Europe based on the environmental and cost effectiveness argument, even if transboundary pollution is reciprocal (in a physical sense), like the case of acid rain. If Eastern European countries value their environmental benefits arising from additional reduction of their pollution loads next to nothing, e.g. $a_{12} > 0$, but $B_1' \approx 0$, then the possibility for emission trading between

'East' and 'West' evaporates and in an economic sense the relation between the two parties is one of unidirectional transboundary pollution, with money payments as the only option for increasing welfare in the two parts of Europe.

4.2 Cost effectiveness

Only national governments have knowledge of their own (subjective) marginal environmental benefits. For that reason it is impossible to assess whether the commitments made in actual international environmental agreements meet the criteria for optimal welfare discussed in Section 2. On the other hand information on costs of pollution control constitutes less of a problem. This makes it possible to assess the cost effectiveness of existing international conventions and even to incorporate clauses in the contract which leave countries the flexibility to transfer the obligation to reduce emissions from one country to the other under the constraint that concentrations or depositions at receptor points do not increase.

The cost minimum is found by maximizing the function

$L = - C_1(z_1) - C_2(z_2) + \lambda_1(\bar{r}_1 - a_{11}z_1 - a_{12}z_2) + \lambda_2(\bar{r}_2 - a_{21}z_1 - a_{22}z_2).$

$\bar{r}_1, \bar{r}_2$ are the concentrations of pollutants that follow from the reductions of emissions that have been agreed. It should be noted that the pollution constraints have the form of inequalities.

The first order condition is

$$\frac{C_1'}{C_2'} = \frac{-\lambda_1 a_{11} - \lambda_2 a_{21}}{-\lambda_1 a_{21} - \lambda_2 a_{22}} \qquad (30)$$

where $-\lambda_1, -\lambda_2$ are the shadow prices of reducing the pollution load in country 1, respectively 2.[11]

It should be noted that the first order conditions for joint maximum net benefits (17), (18) also satisfy the condition for a cost minimum. This should not come as a surprise. If, by accident, the agreement has hit the joint welfare maximum then it is not possible to improve welfare by reducing costs of pollution control, with environmental benefits constant.

Neither the Pareto efficiency condition (10), nor the market solution for reciprocal emission reduction (15), do meet the condition for cost-efficiency. This implies that even if negotiations on reciprocal reduction of emissions have lead to a Pareto efficient agreement there is room left for reallocation of obligations to reduce emissions between countries in order to realize the same environmental benefits at lower cost. Again this would ask for the use of financial compensation. The same is true if the starting point is a combination z_1,z_2 off the contract curve. In cases like this the country with the relative low marginal abatement cost (say country 1) can take over the obligation to reduce emissions from country 2, which has relatively high marginal abatement costs, and receive compensation for its additional costs from the country that can increase its emissions. The case is illustrated in Figure 7. Total costs of pollution control can be lowered (presented by a downward shift of the iso-cost curve) by substituting the initial uniform distribution $\bar{z}_1,\bar{z}_2$ by z_1^*,z_2^*. The binding receptor r_1 defines the trade ratio; $dz_2/dz_1 = -a_{11}/a_{12}$. In the example the pollution load in country 1 and consequently its total environmental benefits remain constant. In country 2 the pollution load decreases and total environmental benefits increase. In this specific case country 2 has a double motive to pay country 1: lower costs as well as higher benefits.

4.3 Pollution load targets (of emission reduction targets) and international transfers

Because of differences of abatement costs and environmental benefits between countries (as perceived by their national governments) the optimal outcome of negotiations on emission reduction might show large differences in percentage of emission reduction between countries. In 'real world' negotiations allowing such differences constitutes a problem because it invites countries to understate their true preferences and try to take a free ride on the abatement offers of others; especially when the number of parties is large. A crude but effective method to prevent such behaviour is to agree on equal or proportional reductions of emissions for everyone; with exceptions only on a few very specific grounds. A very similar approach is to try to agree on uniform pollution load targets and take a programme of cost-effective emission reductions as proposal for abatement obligations. The negotiations

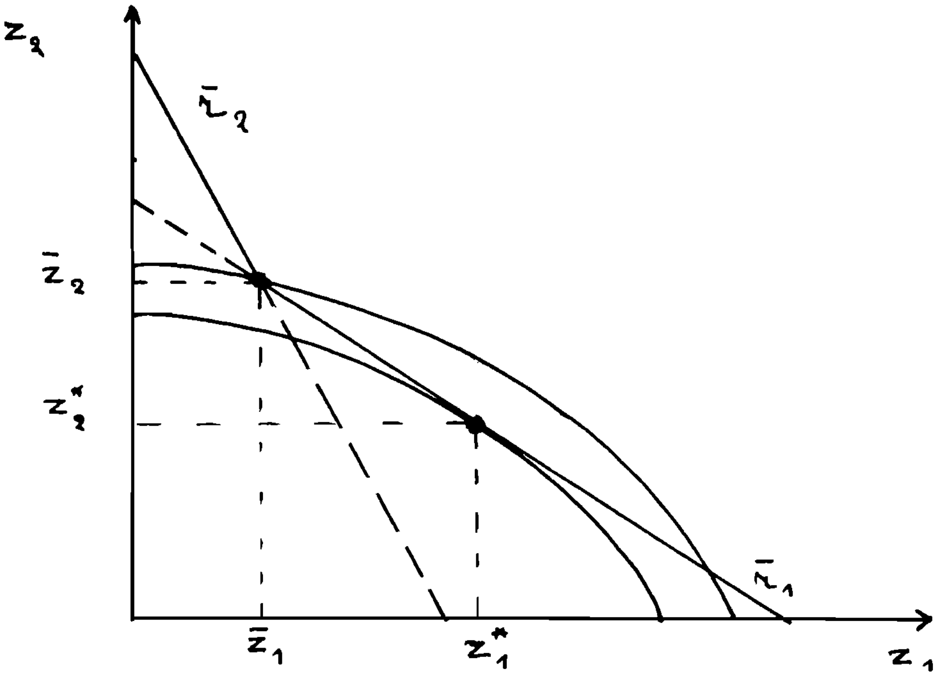


Figure 7

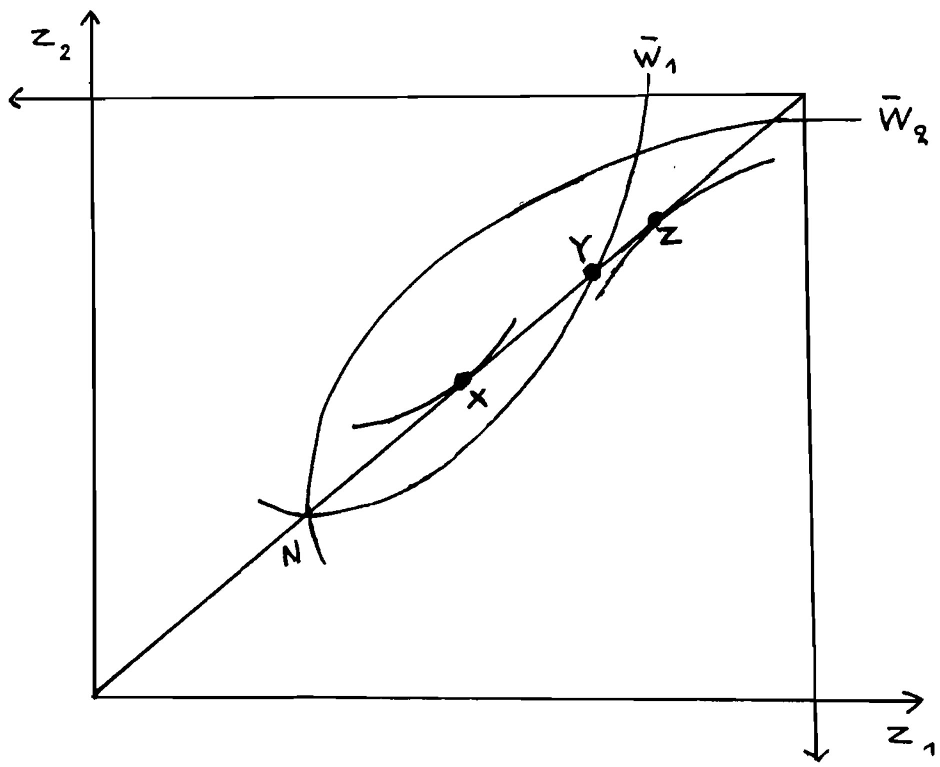


Figure 8

on reduction of SO_2 emissions in Europe offer a good illustration. The Helsinki protocol (1985) was an agreement on a uniform 30 percent reduction of SO_2 emissions in 1993, relative to 1980-emissions. The latest proposals, accepted in principle in May 1993, provide for closing the gap between 1990 pollution loads and critical loads by 60 percent, to be met by 2005 or 2010; in principle the targets will be realized by the cost effective set of emission reductions.

In our two countries model fixing of the pollution load targets at levels $\bar{r}_1$, $\bar{r}_2$ implies that the range of possible emission reductions is constrained by the inequalities

$$\bar{r}_1 \geq a_{11}z_1 + a_{12}z_2 \tag{31}$$

$$\bar{r}_2 \geq a_{21}z_1 + a_{22}z_2 \tag{32}$$

A possible solution that pinpoints z_1,z_2 is to select the cost effective combination by minimizing C_1+C_2 under the constraints (31) and (32). The first order conditions are

$$C_1' = \lambda_1 a_{11} + \lambda_2 a_{21} \tag{33}$$

$$C_2' = \lambda_1 a_{12} + \lambda_2 a_{22} \tag{34}$$

where λ_1 and λ_2 are shadow prices determined by the marginal cost of reducing pollution loads. By fixing $\bar{r}_1$, $\bar{r}_2$ and calculating the cost effective combination z_1, z_2, or by fixing $\bar{z}_1$, $\bar{z}_2$ directly (in the case of uniform emission reduction) all relevant variables are determined. Consequently each party can ascertain what the effect of the proposed protocol will be on its total welfare $W_1 = B_1(\bar{r}_1) - C_1(\bar{z}_1)$, respectively $W_2 = B_2(\bar{r}_2) - C_2(\bar{z}_2)$ (and also what the marginal net benefits are). Given the arbitrary character of the combinations z_1, z_2 and r_1, r_2 it is to be expected that total (and marginal) net benefits differ considerably between countries. It is even possible that against total net benefits for one country the other party has to face a net welfare loss. Such differences could block the acceptance of the actual emission reduction programme by all parties concerned. The probability that at least some countries end up with negative net benefits is higher the more stringent pollution load targets or emission reduction targets are set. This is the natural consequence of increasing marginal cost and decreasing marginal benefits. The first countries to show total net negative benefits are those with modest transboundary benefits from other countries' abatement, because of a low pollution import coefficient or low damage from existing pollution loads.

Transfer payments might be helpful to win the cooperation of reluctant governments. A minimal necessity is full compensation of (perceived) net loss compared to the outcome without agreement; to be paid by the country that enjoys a net welfare gain. A more liberal policy would be to compensate for any reduction of net environmental benefits which would result from overshooting the abatement level that would be welfare maximizing for that country. The transfers are to be paid by the countries that gain in welfare with the restriction that the compensation to be paid is lower than their welfare gain. The potential contributors to the compensation fund are countries with high pollution 'import' coefficients and high damage from existing pollution loads. Since the transfer payments are not meant to induce increases or decreases of abatement at the margin, but are only intended to affect total net welfare, the transfer payments can take the form of lump sum compensation.

In the context of the two countries model the introduction of lump sum transfers implies that the welfare functions of countries 1 and 2 have the form $W_1 = B_1(r_1) - C_1(z_1) + T$ and $W_2 = B_2(r_2) - C_2(z_2) - T$, where T is the lump sum transfer. If the precontract levels of r and z (for example the non-cooperative Nash equilibrium levels) are known the net benefits B-C from the proposed levels of z and r can be assessed by each government. Should country 1 have net negative benefits (B_1-C_1) than it will demand a compensation T that equals the loss B_1-C_1. Country 2 should be able to pay the transfer T and still be better of, thanks to the gain B_2-C_2. If this condition is fulfilled the uniform pollution loads, or uniform reduction of emissions proposal is Pareto dominant compared to the precontract levels of emission, although it probably will not be fully Pareto efficient.

The problem is illustrated in Figure 8. Starting from the non-cooperative Nash equilibrium N the set of Pareto superior positions is represented by the area enclosed by the iso-welfare curves through N. A proposal for proportional reductions of emissions is in discussion, depicted by the linear curve through N. If a proposed equiproportional reduction is presented in the form of a 'take it or leave it' proposal, both countries will accept if the proposal can be represented by a point on the interval NY on the curve of all possible proportional emission reductions, since welfare is higher for both than in N. Proportional reductions, as in point Y, is the maximum acceptable to country 1, without compensation in money. It leaves 1 in the welfare position it had in the non cooperative Nash. If equal reductions are higher, for example on YZ, country 1 will ask monetary compensation for its net welfare loss. The Figure shows that the probability that some countries have to be paid increases with increasing stringency of proportional reductions.

It should be noted that given the implied exchange rate in the proportional reduction proposal the welfare maximizing emission reductions would be for country 1 the point X on its offer curve. All reductions above X are from the point of view of country 1 overshooting and might be an argument for compensation of the resulting welfare loss B_1-C_1 (compared to its individual maximum X). On the other hand country 2 has its individual welfare maximum realized in point Z, on its offer curve. Given the exogenously fixed rate of exchange every increase in proportional reduction moving from Y to Z increases the net welfare B_2-C_2 of country 2 and provides it with the surplus that might be sufficient to compensate country 1.

5. International care

In this section we shall return to the assumption that transboundary pollution is reciprocal, but drop the assumption that all countries are interested only in their own national environment and cost level. It will be assumed that some countries are concerned about environmental quality or economic welfare in other countries. In subsection 5.1 we consider the case of care in country 2 for the environment in country 1. For example Western Europe could be concerned about the environment in Eastern Europe and the opinion could prevail that Eastern European countries have to be supported in their environmental policies. Subsection 5.2 assumes that there exists economic care. The government of country 1 is concerned about the standard of living in country 2 and perceives that this might be lowered by high costs of pollution control in country 1. The question to be answered is to what extent the results from Section 2 have to be modified, if the existence of international environmental and economic care is taken into account and in how far these concerns can be an argument for special international transfers.

5.1 Environmental care

A major motive why inhabitants of a country might care about environmental quality abroad can be their direct interest in the preservation of nature in other countries. As tourists or by way of the media they enjoy nature and landscape in areas far from home. Next to these use values environmental benefit analysis recognizes option value, existence and bequest value as sources of valuation. All these can have an international dimension next to the national scope. Such natural values with transboundary benefits can be affected by transboundary pollution. Acid rain for example destroys forests, and can kill life in lakes. For that reason the government of country 2, representing its subjects, can care about the pollution load (r_1) in country 1.

If country 2 does care for the environment in country 1 then environmental extra territorial benefits of pollution control have to be added to the environmental benefits realized in country 2 itself. In this subsection it is assumed that country 2 does care about the environment in country 1 but not about its costs of pollution control. The welfare function of country 2 than takes the form

$$W_2 = B_2(r_2) + {}^1B_2(r_1) - C_2(z_2) \tag{35}$$

where ${}^1B_2(r_1)$ represents the extra territorial environmental benefits. The introduction of extra national benefits changes the non-cooperative solution. If country 2 considers pollution control by country 1 as given then maximization of

$$L_2 = B_2(r_2) + {}^1B_2(r_1) - C_2(z_2) + \lambda_1(r_1-a_{11}z_1-a_{12}z_2) + \lambda_2(r_2-a_{12}z_1-a_{22}z_2) \tag{36}$$

gives as first order condition

$$C_2' = a_{22}B_2' + a_{12}{}^1B_2' \tag{37}$$

A comparison with (4) reveals that for any given level of z_1 marginal cost C_2' and consequently z_2 will be higher than they would be without altruistic preferences. This implies that inclusion of altruistic preferences makes the reaction curve R_2 shift upwards as is shown in Figure 9. Since country 1 maximizes its own welfare function with national benefits only the Nash non-cooperative will shift from N_e to N_c with z_2 higher and z_1 lower than in the case of egoistic preferences (see also Hoel 1990).

The existence of international environmental care affects the cooperative solution. If countries 1 and 2 would negotiate on reciprocal reductions of emissions and behave as price takers the offer curve for country 2 can be derived from maximizing

$$L_2 = B_2(r_2) + {}^1B_2(r_1) - C_2(z_2) + \lambda_1(r_1-a_{11}\pi_2 z_2-a_{12}z_2) + \lambda_2(r_2-a_{21}\pi_2 z_2-a_{22}z_2) \tag{38}$$

from which we have

$$C_2' = (a_{22}+a_{21}\pi_2)B_2' + (a_{11}\pi_2+a_{12}){}^1B_2' \tag{39}$$

From (39) it follows that

$$\pi_2 = z_1/z_2 = \frac{C_2' - a_{22}B_2' - a_{12}{}^1B_2'}{a_{21}B_2' + a_{11}{}^1B_2'} \tag{40}$$

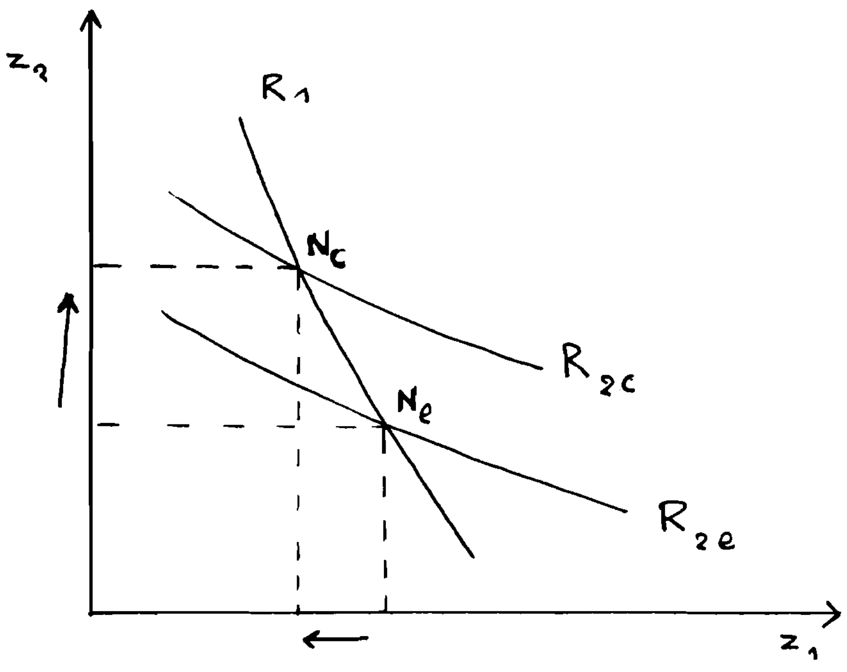


Figure 9

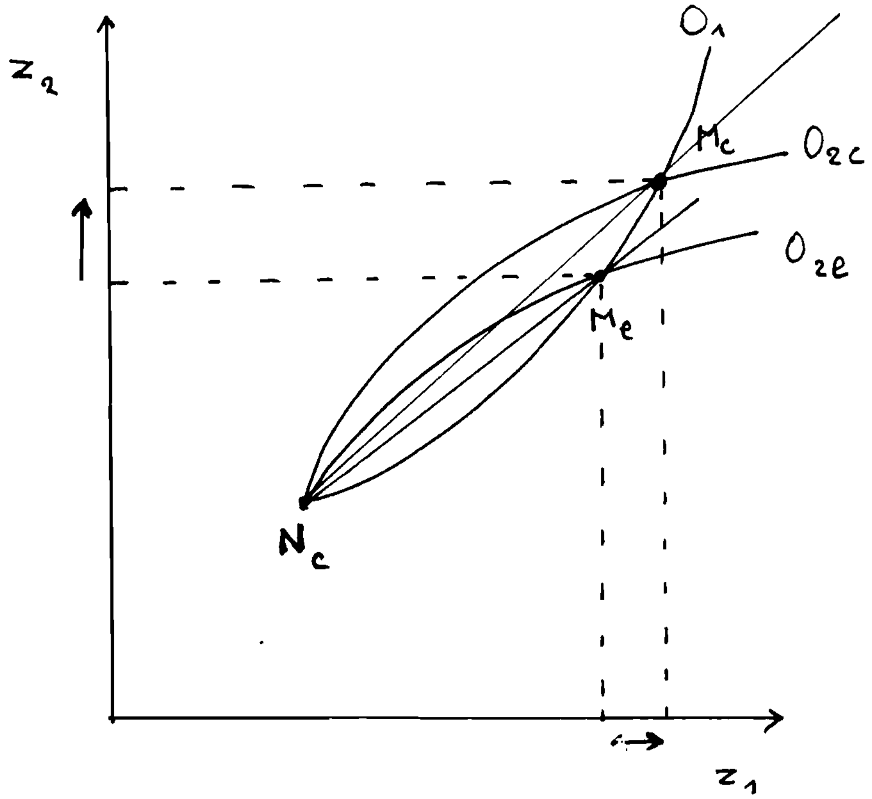


Figure 10

From the properties that $-a_{12}{}^1B_2' < 0$ and $a_{11}{}^1B_2' > 0$ it follows that for a given price π_2 the term $(C_2'-a_{22}B_2')$ must be larger and/or $A_{21}B_2'$ must be smaller than they are in equation (15). This implies that the supply of z_2 by country 2 and its demand for z_1 must be higher than they are without international environmental preferences. This implies a shift in country 2's offer curve from O_{2e} to O_{2c} as indicated in Figure 8. International environmental care makes that at each given level of z_1 country 2 is willing to offer a higher level of pollution control than it would have done with egoistic preferences only.

For country 1 the offer curve is specified by equation (8)

$$C_1' = (a_{11}+a_{12}\pi_1)B_1' \tag{41}$$

From (39) and (41) it follows that

$$\frac{z_2}{z_1} = \pi_1 = \frac{c_1'-a_{11}B_1'}{a_{12}B_1'} = \frac{1}{\pi_2} = \frac{a_{21}B_2'+a_{11}{}^1B_2'}{C_2'-a_{22}B_2'-a_{12}{}^1B_2'} \tag{42}$$

Country 2's higher willingness to control pollution (compared with preferences for the national environment only) makes that in the market equilibrium the exchange ratio changes in the advantage of country 1, as Figure 10 shows. It may look surprising that the existence of environmental care raises the abatement effort of the donor country. The background of this reaction is that increasing emission reduction at home is also a method to improve environmental quality in the neighbour country.

The general conclusion is that altruistic preferences shift the burden of pollution control to the country with international environmental care. In the non-cooperative Nash equilibrium its pollution control will be higher and starting from that position its willingness to offer pollution control at given exchange rate's is higher too. The other country which is the object of environmental care will start from a lower non-cooperative level of pollution control but this is partly or perhaps more than compensated by its higher level of abatement in the market solution induced by the more favourable rate of exchange.

However, in this paper we are not so much interested in the comparative statics of equilibria resulting from reciprocal reduction of emissions as in the improvements that could be brought about by using payments in money next to or in stead of reciprocal emission reduction. Similar to the case of egoistic preferences there is no guarantee that with international environmental care the market solution of reciprocal reduction also is the joint welfare maximum.[12] The first order conditions for maximum joint benefits are

$$a_{11}(B_1' + {}^1B_2') + a_{21}B_2' = C_1' \tag{43}$$

$$a_{12}(B_1' + {}^1B_2') + a_{22}B_2' = C_2' \tag{44}$$

Compared with the case of purely national preferences the term ${}^1B_2$ is added at the benefit side of the first order conditions. This implies that both z_1 and z_2 are higher than with egoistic preferences. Since usually $a_{11} > a_{12}$ (which means that the largest part of emissions will be deposited at home) the joint optimum asks that cet.par. the additional pollution control (compared with joint maximum welfare with national preferences) should be realized mainly by increasing z_1 and not so much by higher z_2.[13]

If country 2 is a rich country with high (subjective) national and international marginal benefits there is a fair chance that at the market solution of reciprocal reduction (and even in the point of disagreement R) a considerable gap is left with country 2's marginal transboundary benefits ($a_{21}B_2' + A_{11}{}^1B_2'$) exceeding country 1's marginal net costs (C_1'-$a_{11}B_1'$). The larger this discrepancy at M (or R) the larger is the international money transfer from 2 to 1 that is needed to increase z_1 and reduce z_2 in order to establish Pareto efficiency with money payments. Under these conditions the benefits of Joint Implementation with international environmental care exceed the benefits from Joint Implementation without environmental care.

Under conditions of reciprocal transboundary pollution the existence of care for the environment in one's neighbour country increases the probability that the joint maximum can not be attained by way of reciprocal reduction of emissions. This is in particular true if the country that cares is relatively rich, has strong environmental preferences and high (marginal) costs of pollution control. Should country 2 try to improve environmental quality in country 1 by offering additional pollution control in country 2 that would be a very expensive solution indeed. Instead country 2 can pay country 1 for pollution control undertaken by country 1 itself. The money is given by the donor country with the intention to raise abatement effort and to improve environmental quality in the receiving country and at home as well. The existence of international environmental care does not ask for a special financial instrument. But what it does, under plausible conditions, is to raise the gains from Joint Implementation.

5.2 Economic care

Pollution control uses up factors of production which are diverted from other uses. Raising the level of pollution control implies that real income available for consumption and 'productive' investment will be lower. A donor country might care about the negative impacts of environmental regulation on the standard of living in economically less developed countries. It shall be shown in this subsection that the existence of international economic care has impacts which are largely the opposite of the consequences of international environmental care. The economic care motive is modeled by adding a variable to the welfare function of the rich country which represents care about the costs of pollution control in the poor country. Let country 2 be the country that cares and ${}^1C_2(z_1)$ the economic care variable, with ${}^1C_2' < 0$, ${}^1C_2'' < 0$, that is increasing marginal disutility.

If country 2 does not consider the granting of a subsidy and has to act in a non cooperative situation it maximizes the function

$$L_2 = B_2(r_2) - C_2(z_2) - {}^1C_2(z_1) + \lambda_2(r_2 - a_{21}z_1 - a_{22}z_2) \tag{46}$$

Since z_2 is the only action parameter and transnational benefits are not taken into account the first order conditions for a non cooperative Nash equilibrium will be equal to first order condition (4). The introduction of international economic care does not affect the levels of pollution control in the non cooperative Nash equilibrium.

When there is the possibility of cooperation in the form of reciprocal reductions of emission, but without the use of money payments the offer curve of country 2 is derived by maximizing

$$L_2 = B_2(r_2) - C_2(z_2) - {}^1C_2(\pi_2 z_2) + \lambda_2(r_2 - a_{21}\pi_2 z_2 - a_{22}z_2) \tag{47}$$

Since country 2 is not interested in the state of the environment in country 1 the deposition constraint for country 1 is left out. The function ${}^1C_2(z_1) = {}^1C_2(\pi_2 z_2)$ says that country 2 takes into account that its offer of z_2 will induce country 1 to increase z_1 and by consequence its costs of pollution control. The first order condition is

$$C_2' = (a_{22} + a_{21}\pi_2)B_2' - \pi_2 {}^1C_2' \tag{48}$$

or

$$\pi_2 = \frac{C_2' - a_{22}B_2'}{a_{21}B_2' - {}^1C_2'} \tag{48a}$$

Compared with (15) equation (48a) has an additional value $-{}^1C_2'$ in its denominator. This implies that for a given value π_2 both z_1 and z_2 have to be lower than they would be if economic care did not exist (assuming that $a_{21}B_2' > {}^1C_2'$). As is shown in Figure 11, country 2 will be offering less z_2 at any given z_1 with economic care than it would have if it did not care about income in country 1.

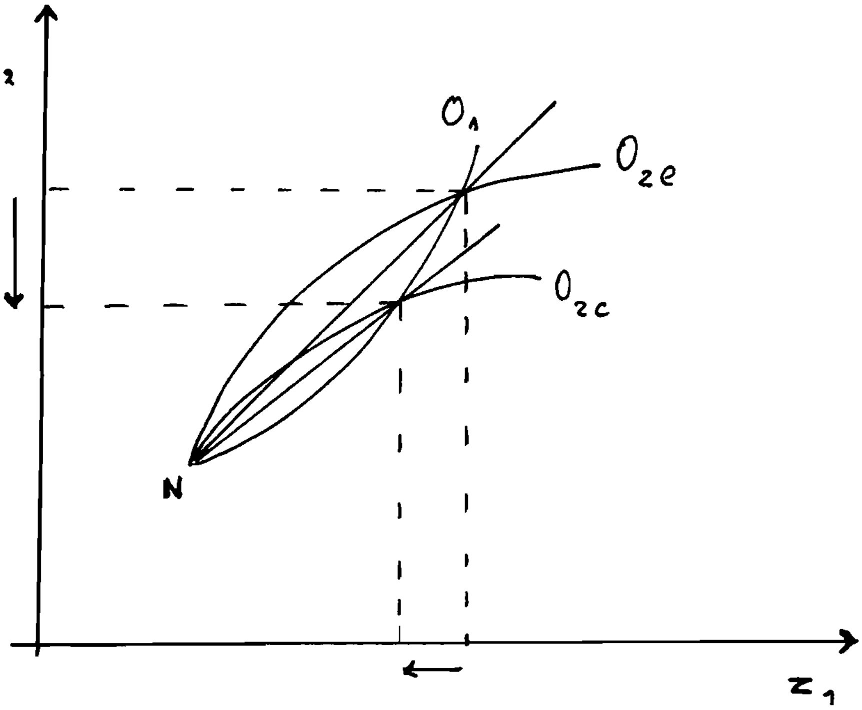


Figure 11.

Country 1 maximizes its welfare function as modeled in equation (11) and first order condition (13). Consequently the market equilibrium derived from (13) and (48) is

$$\frac{z_2}{z_1} = \frac{C_1' - a_{11}B_1}{a_{12}B_1'} = \frac{a_{21}B_2' - {}^1C_2'}{C_2' - a_{22}B_2'} \qquad (49)$$

It can be derived from (49) and is visualized in Figure 11 that economic care of country 2 for country 1 makes that the rate of exchange z_2/z_1 is less favourable for country 1 in a market equilibrium of reciprocal emission reduction. This may seem strange at a first look but has a simple explanation. An unfavourable rate of exchange discourages pollution control in country 1. Therefore its costs of pollution control are lower, which is to the satisfaction of country 2. Since country 1 is on a lower point on its offer curve its actual welfare is lowered: the reduction of environmental benefits exceeds the reduction in pollution control costs. This is a consequence of country 2's neglect of environmental quality in country 1.

Welfare in both countries could be improved if payments in money are applied. In order to find the Pareto optimum with money payments (a maximum joint welfare) the function ${}^1C_2'(z_1)$ has to be added to (16) and in order to find the market solution with money payments between parties the same function has to be added to (20). Maximization of amended equation (16), respectively of (20) and (19) gives as first order conditions

$$C_1' - a_{11}B_1' = a_{21}B_1' - {}^1C_2' \qquad (50)$$

$$C_2' - a_{22}B_2' = a_{12}B_1' \qquad (51)$$

or

$$\frac{C_1'}{C_2'} = \frac{a_{11}B_1' + a_{21}B_2' - 1C_2'}{a_{12}B_1' + a_{22}B_2'} \qquad (52)$$

Economic care depresses country 2's willingness to pay for reduction of country 1's control of pollution. Consequently the extent to which the marginal benefits of transboundary pollution reduction of country 2 ($a_{21}B_2'$ - ${}^1C_2'$) exceed net marginal cost of country 1 (C_1' - $a_{11}B_1'$) in the market solution of reciprocal emission reduction is decreased too. This implies that the scope for improving welfare in both countries by payments from rich country 2 to poor country 1 in exchange for additional pollution control by country 1 is decreased by the existence of economic care.

6. Conclusion

There are good economic arguments for international money transfers in the context of international agreements on reduction of pollution. In the case of reciprocal transboundary pollution the possibilities to reduce emissions on a reciprocal base can be constrained by sharply increasing marginal costs and low national marginal benefits from pollution control at home in one of the countries. By taking recourse to payments in money an additional means of exchange becomes available that increases the scope for exchanges that are beneficial for both parties. If the 'purchase' of additional reductions of emissions abroad by offering extra pollution control at home has become too expensive, because of high net costs of pollution control a country still may have the option to offer money (i.e. part of its real income), in exchange for emission reduction to countries that have relatively low marginal costs of pollution control and low internal environmental marginal benefits. The advantage of using money payments is even larger if the countries with the high marginal net costs of pollution control are those with high real national incomes. Cet.par. a rise in real income will raise the willingness to pay in terms of (international) money for reduction of transboundary pollution. Total costs of pollution control can be reduced and environmental benefits increased for all countries concerned.

Two simple systems of financial compensation have been discussed. One system applies reciprocal payments for each additional unit of pollution control. If parties are willing to reveal their true net benefits from environmental protection a procedure of tâtonnement would lead up to a kind of market equilibrium in which some countries would have a net expenditure of money and others a net income from their pollution control.

The same equilibrium position could also be realized by way of a procedure which consists of two steps. In the first stage the negotiations have the form of reciprocal reductions of emissions and the best possible (Pareto optimal) solution, that is feasible within the constraints of this procedure can be searched. The next step consists of reallocation of pollution control which is such that some parties increase their abatement of emissions and are paid for that by the countries who decrease their abatement effort.

The two steps procedure is a fair approximation of that what happens in the real world. Negotiations usually take the form of reciprocal reduction of emissions. Only recently countries seem to have discovered the advantages of the second step: that is revising the emission allocation of the first stage and allowing payment in money to bring about the reallocation of national obligations to control pollution. This is what Joint Implementation in essence is.

All the other cases of international payments for the control of transboundary pollution, discussed in this paper, actually are specific cases of the general principle that net benefits of transboundary pollution control can be increased by bringing in money payments. (1) In the case of unidirectional transboundary pollution the first stage of reciprocal reduction of emissions is not feasible and only the second stage of making international payments for emission reduction rests to make an international agreement on emission reduction possible.

The compensation to be paid for the last unit should be set equal to the marginal transboundary benefit. The argument also holds if there is reciprocal transboundary pollution but one of the parties does not attach a positive value to additional reduction of its pollution at home.

(2) If the (subjective) environmental benefits of pollution control can not be ascertained but costs are well known, Joint Implementation, as a complement to an agreement on reciprocal reduction of emissions, can be geared to reallocation of emission reduction between parties in such a way that total costs of pollution control are lowered, without impairing environmental quality in the countries. The country that accepts the obligation to intensify its abatement effort has to be compensated for the additional cost.

(3) If there exists international environmental care the caring country can encourage additional reduction of emissions in the country for which environment it cares by offering that country a more favourable rate of exchange in the negotiations on reciprocal reduction of emissions. As a complement and in the context of Joint Implementation the country that cares can propose to pay for additional reductions of emissions in the country it cares for with a simultaneous increase of emissions at home.

(4) If economic care exists in a context of reciprocal transboundary pollution the country that cares can encourage the country it cares for to reduce its pollution control and pollution control costs by offering a less favourable rate of exchange in the negotiations on reciprocal reduction of emissions. When money payments are added pollution control can be reallocated to the benefit of both parties.

The analysis of international care leads up to the conclusion that its existence does not necessarily demand a special kind of subsidy. The desired outcomes can be realized in the process of negotiation on reciprocal reduction of emissions. Supplementing this with Joint Implementation will not change the outcome basically. This implies that the arguments for a potential investment fund for Eastern Europe are not essentially different from the reasons for forming such a fund for Western Europe. Nor should the principles that determine the payments to and receipts from the fund differ from the guidelines for Joint Implementation between Western European countries.

(5) If international agreements take the form of uniform or proportional reduction of emissions, or of pollution loads, lump sum transfers can be necessary in order to compensate countries with negative net benefits and to win their cooperation. These payments differ in

character from the ones mentioned earlier. They are necessary in order to make the proposed agreement on reciprocal reduction of emissions feasible. Once such an agreement has been made there is scope for Joint Implementation actions. With uniform reductions as the first step of the agreement the second step will be directed to (improving) cost effectiveness.

Joint implementation is clearly defined as cooperation between countries which are parties to an international convention that demands reciprocal reduction of emissions. We have seen that scope for such welfare improving post contractual concerted action is largest if the international contract that stipulates the reduction of emissions cannot be an optimal one. We mentioned uniform or proportional reduction of emissions and agreements on pollution load targets as relevant examples. Transfer of emission reduction obligations between countries in exchange for a money transfer can then be a form of Joint Implementation that increases the cost-effectiveness of a non-optimal international convention. To some degree it will improve its environmental effectiveness too. The Convention on Climate Change, with its undifferentiated stabilisation of emissions by 2000 on the 1990 level for signing parties, is a clear candidate for such 'post-contractual' transfers.

NOTES

1. According to article 2.5 countries which are relatively small producers of CFC's are allowed to transfer to or receive from any other party to the Protocol production in excess of its limits, provided that the combined levels or production of the parties concerned do not exceed the production limit. Article 2.8 allows consumer countries to fulfil their obligations jointly respecting consumption, provided their total combined consumption remains below required limits.

2. Recently Johansson (1992) has discussed the place for altruism in cost benefit analysis.

3. This type of utility function is generally used in the literature on international pollution; e.g. Mäler (1990), Hoel (1991).

4. The concepts of Nash non-cooperative equilibrium and Pareto equilibrium are by now a part of common wisdom in the analysis of international pollution problems; see Pethig (1982), Nentjes and Wiersma (1984), Nentjes (1990), Hoel (1991).

5. Maximization of W_2 under the constraint of W_1 gives the same first order condition.

6. In Hoel (1991) the Nash bargaining solution is taken as the point of reference for making comparisons.

7. See for a mechanism that possibly could solve the problem Tulkens (1991) and Chander and Tulkens (1991).

8. r_1, r_2, z_1, z_2 refer to additional reductions relative to the Nash non-cooperative solution.

9. If $a_{12} = 0$ the iso welfare curve $\bar{W}_1$ in figure 2 transforms into a vertical curve through point N and the set Pareto dominant solutions from emission trading shrinks to zero. There exists no possibility to increase welfare by way of reciprocal reduction of emissions.

10. It should be noted that the cost-effectiveness motive is met simultaneously with environmental effectiveness: emission abatement is in both countries set at the level where the marginal environmental benefits per DM expended on abatement in country 1 and 2 are equal to one DM:

$$\frac{a_{22}B_2'}{C_2'} = \frac{a_{11}B_1' + a_{21}B_2'}{C_1'} = 1$$

11. The constraint qualification asks that the number of binding constraints is less than the number of variables, therefore only one constraint can be binding in the cost minimum of our example.

12. The first order condition for a Pareto optimum with international environmental care but without side payments is

$$\frac{C_1' - a_{11}B_1'}{a_{12}B_1'} = \frac{a_{21}B_2' + a_{11}{}^1B_2'}{C_2' - a_{22}B_2' - a_{12}{}^1B_2'}$$

A comparison of (45) with (42) reveals that with international environmental care the market solution of reciprocal reduction is a point on the Pareto optimum curve of reciprocal reduction. Like in the case of only national environmental preferences the joint maximum welfare, equations (43) and (44) can be rewritten as a Pareto-solution, but not the other way round. This implies again that joint maximum welfare is a special case of the Pareto optimum. Consequently additional financial instruments have to be applied in order to realize the joint welfare maximum.

13. This contrasts with the market solution of reciprocal reduction of emissions which suggested that country 2 should take the lead in controlling pollution (compared with egoistic preferences).

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