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BILATERAL TRANSFERS AND LENDING IN INTERNATIONAL ENVIRONMENTAL COOPERATION

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ABSTRACT: The paper analyzes environmental lending and transfers in a two country general equilibrium framework. The lender country chooses specific environmental investments which it finances in the neighbour country on the basis of the returns they generate for the lender. The properties of this kind of international environmental financing are evaluated and the gains of it are illustrated with a numerical calibration of the model showing that the gains to the lender country may be fairly sizable in relation to the expenditure directed currently towards environmental protection. These gains, however, essentially depend on the terms of the environmental financing. We also find that debt-for-nature swaps do not in general produce efficient environmental protection if applied uniformly in international environmental financing.

KEY WORDS: International environmental cooperation and financing, environmental investment

Kari Alho

Bilateral Transfers and Lending in International Environmental Cooperation*

1. Introduction

International environmental cooperation is efficient if it leads to a situation where the countries carry out all environmental projects, the yield on which, when measured on a global level, is at least as high as the uniform time preference. This kind of full-scale cooperation has been studied and the full cooperative solution for environmental policies has been numerically estimated, either as a multinational game by Mäler (1989,1990), see also Newbery (1990), or as a regional two country game by Kaitala, Pohjola and Tahvonen (1990). These analyses yield the benefits of cooperation as compared to autarky and also the necessary transfers to be carried out so that all countries equally share the gains from cooperation and have thereby an incentive to cooperate.

However, in practice it is not very likely that countries would engage in such overall cooperation in their environmental policies once and for all. We mostly see international agreements of the type of equal stepwise cuts in emissions by the participating countries. Under such a scheme each country is likely to carry out those projects which give it the highest yield. Therefore these agreements may not produce large enough cuts in the international environmental externalities for some nonsymmetric cases, in addition to not being cost effective. Thus for example, Finland has made a regional agreement with the Soviet Union reducing emissions in Finland and the neighbouring parts of the Soviet Union.[1)]

In addition, or as a complement to agreements between nations, the net victim countries, i.e. net importers of pollution, may find it in their interest to finance some specific environmental protection in a neighbouring country with a transfer or a loan on soft terms. Accordingly, various kind of financing arrangements are being considered intensively at present to improve the environment in developing countries and in Eastern Europe, partly with the aid of the Western countries. Particularly, the Nordic countries have initiated bilateral and multilateral environmental financing programs with Poland and the Soviet Union. One reason for these plans is the high spillover yield from these environmental investments accruing to the donors as compared to projects carried out in the home country, where environmental protection is already faced with the problem of diminishing returns on additional projects. The basic problem we want to address in this paper is the financial subsidization related to a neighbour country's environmental protection and its welfare implications for the partner countries.

The problem where a country wants to a influence its neighbour's environmental policies with various kind of financial subsidies or incentives has usually been linked in the literature to the developing countries' resource extraction policies, which have caused alarm in the developed countries due to their grave global environmental consequences. The effects of various financial operations by the developed countries on these policies of the developing countries has been analyzed by Strand (1990a,b), see also Rauscher (1989) and the general introduction by Hansen (1989).

In the cooperative framework all the participating countries care for their environment, while the resource extraction literature seems to have concentrated on the case where only the developed countries, the donors, care about the (global) environment. In the following our aim is to combine financial transfers to the framework of environmental cooperation where also the recipent countries' preferences towards the environment essentially influence the outcome of these international environmental financing operations.

Our framework is cast in a simple static general equilibrium framework of two countries and two goods, a material commodity and the quality of environment. We allow for a whole range of the environmental projects and combine the terms of the environmental financing extended by the donor countries to the analysis. These turn out to be quite essential as to the outcome of the environmental financing operations.

The paper is organized in the following way. In section 2 we specify our model and study as reference cases the noncooperative Nash equilibrium under environmental autarky and the full cooperative solution. In section 3 the case of unilateral selective environmental financing is analyzed and the conditions for its efficiency and its properties, as well as some problems likely to be encountered in practice, are evaluated in section 4. Section 5 presents a numerical illustration on the welfare effects of the selective environmental financing on the donor country. Section 6 concludes the paper and considers some limitations and extensions of the analysis.

2. The model and environmental policies under autarky

We concentrate on the case of two nations which are denoted by H (home) and F (foreign). Basically we consider the home country to be the active partner in striving at environmental cooperation and it is also potentially willing to carry out financial transfers for F to promote this goal. Each country i has been given initial resources (production) W_i of the single material good, which is produced and used by both countries and which can be allocated into four alternative uses in the current period: to current material consumption C_i, to investment H_i into productive capital in order to increase future material consumption D_i, to investment I_i into environmental protection to produce more of the environmental good E, i.e. an improved environment in the next period, and last, to net exports, which is identical to net foreign lending L_i.

The constraints binding the decision-making which essentially describe the productivities of the investment outlays are of the following kind,

$$(1) \quad D_i = F_i(H_i) + (1+r^*)L_i, \quad F'_i = f_i > 0, \; F''_i < 0 \; ,$$

$$(2) \quad E_i = E_{ii}(I_i) + E_{ji}(I_j),\ E'_{ii} = e_{ii} > 0,\ E''_{ii} < 0 \text{ and } E'_{ji} = e_{ji} > 0 \text{ , and}$$

$$(3) \quad W_i = C_i + H_i + I_i + L_i \ .$$

The first constraint describes the decision making between the current and future consumption of the material good, with F denoting the productivity of the material investment. The material good is taken to be common to both countries and it serves as the numeraire and means of international payments. All current period relative prices, exchange rate and monetary considerations can thus be omitted from the model. Trade in the material good is paid so that it is shipped in the next period by the buyer (borrower) to the seller (lender) country, hence the latter term in the constraint (1). The international real rate of interest r* is taken to be given to the countries. The third constraint is the national budget constraint.[2)]

The second constraint describes the production of an improved environment and the international externalities related to it. The function E_{ij} denotes the environmental spillover benefits created to country j by environmental investment in country i. The marginal spillover functions e_{ij} may have quite a peculiar irregular form and one maximum or several maxima at positive values of investment which the e_{ii}-functions by definition do not have.[3)] One major reason for this situation is the dissimilarity in geographic conditions between the two countries which may cause that the best environmental investments in country i, from the point of view of j, may well be those which are not set as a top priority by country i. We only know for sure that the e_{ij}-function is nonnegative and approaches zero with sufficiently high levels of investment.

As specified in (2), there is assumed to be no interaction between the physical productivities of the environmental investments in the two countries.[4)] So there are essentially two separate production lines, domestic and foreign, with different productivities for improving the environment in each country.

The policies are solely analyzed here on a national level.[5)] The decision-making of each country is accordingly based on a national welfare function

(4) $U_i = U_i(C_i, D_i, E_i)$.

This has the normal properties of positive marginal utilities and concavity.

By substituting the constraints (1), (2) and (3) into the objective function (4) we can derive the necessary and sufficient conditions for an inner point optimum for the noncooperative decision-making under autarky in environmental protection. By derivativing with respect to the material and environmental investment, and international lending, we get

(5a) $$U'_{Di} f_i - U'_{Ci} = 0$$

(5b) $$U'_{Di}[(U'_{Ei}/U'_{Di})e_{ii}] - U'_{Ci} = 0$$

(5c) $$U'_{Di}(1+r^*) - U'_{Ci} = 0 .$$

The marginal rate of social time preference, denoted by σ in the following, can be stated in the normal way,

(6) $$U'_{Ci}/U'_{Di} = 1 + \sigma_i .$$

The allocation criteria (5a) and (5c) produce the familiar condition of equality between the marginal productivity of the material investment and the international real rate of interest. The optimal intertemporal allocation of consumption is derived from the equality between the time preference (6) and the marginal productivity of investment (5c). So we have

(7a) $$f_i = 1+r^* = 1+\sigma_i .$$

Note that all the marginal returns f_i, e_{ii} and e_{ij} include here the initial capital outlay. In optimum the return on an environmental investment in terms of material consumption has to be the same as that on a material investment, i.e. the social time preference. So we have from (5b)

(7b) $$[U'_{Ei}/U'_{Di}]e_{ii} = 1+\sigma_i \quad .$$

We also have that $\sigma_i > 0$ as we assume $r^* > 0$. The condition (7a) when obeyed by both countries implies that in equilibrium the marginal rate of social time preference should be the same in both countries, if they are both efficiently integrated in the world financial markets,

(7c) $$\sigma_H = \sigma_F = \sigma \quad .$$

This is a straightforward standard result of international economics, which we have assumed all through the following analysis. If this were not the case, e.g. due to credit rationing in the international financial market as a result of overindebtedness of the recipient F country, we would have a richer but more complex framework. However, we have decided only to confine to differences in the environmental spillovers and preferences between the countries and therefore omit this enlargement here.

Let us now study the noncooperative Nash equilibrium with respect to the environmental investment. The reaction function, denoted by $I_H = R_H(I_F)$, of country H's environmental investment as a function of country F's environmental investment can be written on the basis of (5b) as follows in the simplified case of separable utility between the environment and the current consumption,[6)]

(8) $$R'_H = \left(\frac{dI_H}{dI_F}\right)_H = -\frac{U''_{EH}e_{FH}e_{HH}}{U''_{EH}(e_{HH})^2 + U''_{CH} + U'_{EH}e'_{HH}} \quad .$$

The noncooperative Nash equilibrium lies at the point of intersection of the reaction functions R_H and R_F. From (8) we see that the slope of the reaction function is negative and it is (in absolute terms) certainly less than unity if $e_{FH} < e_{HH}$, i.e. if the marginal spillover benefit to H from the neighbour's environmental investment is less than the yield to H from a national investment. In this case if there is a Nash equilibrium, it is unique, as the reaction curves can now intersect at most once. In figure 1 we assume this to be the case. However, we may well think about the case of multiple equilibria. It should also be noted that the reaction curves do not necessarily intersect each other at all if one of them (that of country F) lies inside that of country H.[7] The reaction function of country F may also coincide with the horizontal axis, which takes place if country F is in a corner optimum with no environmental investment.

The indifference curves may also have kinks in the plane due to the possible irregularities in the e_{ij}-function mentioned above. The indifference curves of country H are horizontal where they intersect its reaction function R_H and those of the F country are vertical on its reaction function.[8] Thus the indifference curves intersect each other in the usual way in the Nash equilibrium and therefore there is room for cooperation which is beneficial for both countries in the area between the indifference curves going through the Nash equilibrium. The contract curve CC of Pareto-efficient solutions is located in this region.

To analyze cooperation, the utility functions U_i are next transformed into a common unit of account by dividing the changes in utilities with respect to the Nash equilibrium by the corresponding marginal utility of the present material consumption and these differentials are then denoted by the symbol dU^*_i. The efficient cooperation between the two countries when side payments, i.e. transfers, are possible between them is given by maximizing the sum

(9) $$dU^* = dU^*_H + dU^*_F \quad .$$

Note that as all the benefits and costs of the material investment are taken to be internal, there is no need to coordinate them and the conditions (7a) and (7c) hold as such also now. We can derive the following global optimality condition for the environmental cooperation and the investment to be carried out in country F, corresponding to (7b),

(10a) $$[U'_{EH}/U'_{CH}]e_{FH} + [U'_{EF}/U'_{CF}]e_{FF} = 1 \quad .$$

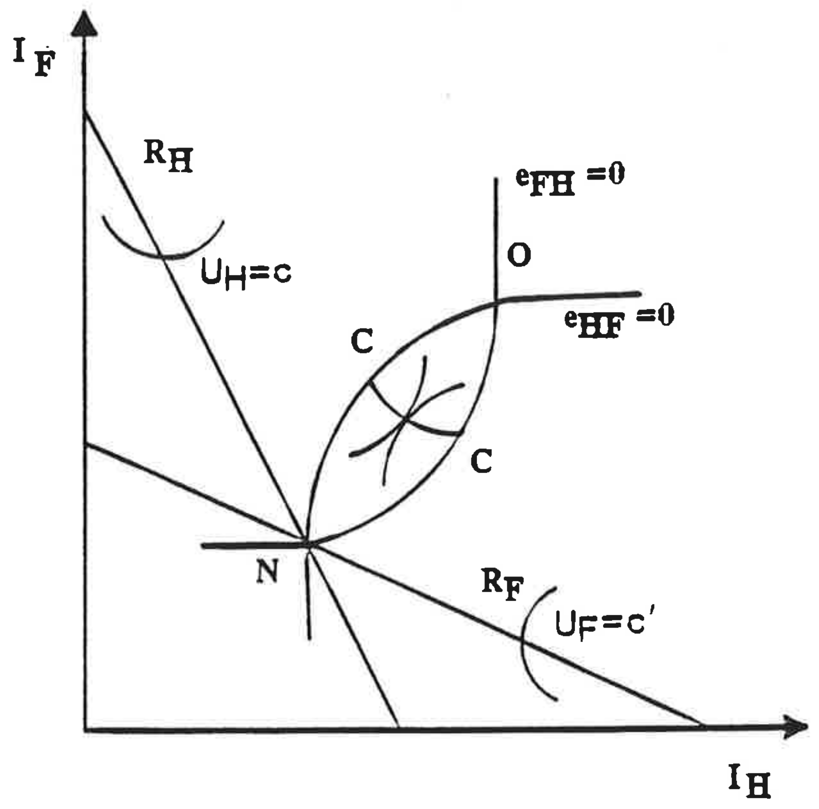
With the aid of (5b) this expression can be written as follows,

(10b) $$[U'_{EH}/U'_{DH}]e_{FH} + [U'_{EF}/U'_{DF}]e_{FF} = 1 + \sigma \quad .$$

This means that the two countries form an efficient environmental pool so that the global yield on environmental investment measured in the respective consumption prices is set to be identical with that on the material investment, i.e. the time preference. The condition (10b) and a similar one for country H's environmental investment define a unique point on the contract curve. The transfer between the countries can then be carried out in such a way that both countries get an equal net benefit from their cooperation, an outcome suggested by the symmetric Nash bargaining solution.

The point O in figure 1 is also of interest because at this point the marginal environmental spillover yield (e_{HF} or e_{FH}) to the neighbouring country becomes zero, (see footnote (8)). This is thus a situation of extreme environmental altruism of the coun-

Figure 1. The reaction functions and the Nash equilibrium related to the environmental investment in the two countries.



tries towards each other, because one (or both) of them does everything it can to improve the neighbour's environment. In effect this would mean that there would not any more exist international environmental externatilities e.g. in the form of transboundary air pollution. However, we immediately see that this is not an efficient environmental cooperation, because the countries always find a better cooperative solution as the indifference curves intersect in such altruistic points. So, international environmental externatilities exist also under optimal international cooperation, analogously as in the standard case of externalities.[9)]

3. Selective international environmental financing

Let us next introduce the possibility of a transfer or more generally lending and borrowing at below market rates between the countries on a selective, projectwise basis. The loan or a part of it is repaid in the second period. We assume that the home country H is the donor (the lender) and country F is the recipient (borrower). We solely consider a financial arrangement where country H chooses, from its own point of view, those environmental projects it wants to finance in country F. Therefore we can call it selective international environmental financing.

Now country H chooses an interval or several intervals - in the limiting case a set of individual projects - from the I_F-line which it wants to finance. In the following we concentrate without loss of generality on the case of a single interval denoted by $[I_F^0, I_F^1]$.

This environmental financing has both a substitution and an income effect on the behaviour of country F. Let us start from the income effect. To derive it we have to evaluate the value of the transfer, denoted by dW_F, for country F in terms of the current period material consumption. Let T be the quantity of the transfer or loan in terms of the material good, i.e. it is the length of the interval, and r the interest rate on it. The value of the transfer for country F is the following,

(11) $$dW_F = (U'_{EF}/U'_{CF})[E_{FF}(I_F^1) - E_{FF}(I_F^0)] - T(U'_{DF}/U'_{CF})(1+r),$$

$$\text{where } T = I_F^1 - I_F^0 \quad .$$

The first term describes the value of the additional environmental investment to F. The second term represents the burden of the amortization and interest on the loan. This term can be approximated by $T(1+r)/(1+\sigma)$ with the aid of (5b). The expression (11) can then be written, using again (5b) in the first term, as follows

(12) $$dW_F = T\left(\frac{e^0_{FF}}{e^N_{FF}} - \frac{1+r}{1+\sigma}\right) ,$$

where e^0_{FF} is the value of e_{FF} in the point I_F^0 and e^N_{FF} is the value of e_{FF} in the Nash equilibrium.

Note that in country F the environmental investments are in general not increased from the Nash equilibrium onwards, because H chooses the projects in its own interest. This lowers the value of the transfer to F. If F could unconditionally choose the projects in its own interest, the first term in brackets in (12) would be unity and the value of the transfer would be equal at its full monetary value $T[1-(1+r)/(1+\sigma)]$. A loan at the market rate of interest does not cause in this case an income effect.

In general, a transfer with an effect on the budget constraint of the receiver - and the lender - country (see (14) below) leads through the income effect to a change in its allocations, also in its environmental investment. Let us denote by I_F^N the environmental investment carried out by F with its own resources, i.e. those of the Nash equilibrium. It is helpful to split the income effect of the financing operation into two parts,

(13) $$\frac{dI_F^N}{dT} = \frac{dI_F^N}{dW_F}\,\frac{dW_F}{dT} \quad .$$

The first factor on the right-hand side is analogous to the income effect of the standard consumer theory, see e.g. Intriligator (1971), pp. 154-158. In the following let us denote this income effect by μ_F, and similarly for country H. We need not delve more closely into this expression which depends on the second order properties of the objective function (4) in the Nash equilibrium. We take this income effect to be non-negative but below unity in the following, which means that the environment is a normal good. The second term in (13) is given by (12).

The environmental investments to be carried out in country F consist now of the intervals $[0,I_F^N]$ and $[I_F^0,I_F^1]$. If the latter interval financed by country H lies inside the former, we have the situation where the own environment investment carried out by F is reduced because H finances them, i.e. the substitution effect $(dI_F^N/dT)_S$ is minus unity. If these intervals do not coincide, there is no "crowding out" and we have $(dI_F^N/dT)_S = 0$.

For the lender country H the cost of the lending operation is respectively in terms of its current material consumption

$$(14) \qquad -dW_H = T - (U'_{DH}/U'_{CH})T(1+r) = T(1- \frac{1+r}{1+\sigma}) \ .$$

With the interest rate less than the time preference the lender bears a cost in terms of foregone consumption and it has to weigh this against the increased benefits in terms of its environmental spillovers.

The objective of country H is to choose the financing interval in such a way that the increased environmental spillover benefits related to the interval less the cost of the lending operation as shown in (14) is maximized. It is a natural constraint for H when it plans the projects it is going to finance and the interest on it that the welfare of country F cannot be reduced as a result of these operations. Let us turn to derive this constraint next.

The (net) benefit to F was presented by the value of the transfer or loan in (10). There is an additional indirect cost caused to F by the fact that the transfer tightens the budget constraint of country H which normally leads to a reduction in its environmental investment, and through this also leads to lower spillover benefits to country F. So we have

$$(15)\qquad \frac{dU_F}{dT} = U'_{EF}e^N_{HF}\mu_H(\frac{1+r}{1+\sigma} - 1) + U'_{CF}(\frac{e^0_{FF}}{e^N_{FF}} - \frac{1+r}{1+\sigma}) .$$

The first term describes the loss for F caused by the cut in the environmental investment by H (from the Nash equilibrium downwards). The second term is the marginal value of the transfer to F presented above in (12). Equation (15) should be nonnegative so that country F would be willing to cooperate with H in environmental financing. From (15), using (5b), we can solve the range of the interest rates r which is profitable for country F to be

$$(16)\qquad \frac{1+r}{1+\sigma} \leq \frac{e^0_{FF}/e^N_{FF}-(e^N_{HF}/e^N_{FF})\mu_H}{1 - (e^N_{HF}/e^N_{FF})\mu_H} .$$

Let us solely concentrate on the case where country H finances extramarginal projects in country F, which implies that $e^0_{FF} < e^N_{FF}$. We may now easily infer from (16) that the higher μ_H is, the lower the highest profitable interest rate for country F, as is plausible. We can therefore write (16) as $e^0_{FF}/e^N_{FF}-\delta(\mu_H)$, $\delta(0)=0$, $\delta'>0$. The actual interest factor $(1+r)/(1+\sigma)$ related to the project I_F^0 is $e^0_{FF}/e^N_{FF}-\delta-\alpha$, where α (≥ 0) describes the net benefit required by country F from the project (I_F^1 or I_F^0) concerned.

Let us now derive the optimal interval of environmental projects to be financed by H in country F. First we keep the interest rate r as given and then incorporate the constraint (16) into the analysis in the next section. The additional spillover benefit to H is described by the term $E_{FH}(I_F^1)-E_{FH}(I_F^0)$ and the cost of finance by (14). The optimum condition for the upper point I_F^1 of the interval concerned is now

$$(17)\qquad U'_{EH}[e^1_{FH} + e^1_{FH}\left(\frac{dI_F^N}{dT}\right)_S + e^N_{FH}\mu_F(\frac{e^0_{FF}}{e^N_{FF}} - \frac{1+r}{1+\sigma})] - U'_{CH}(1-\frac{1+r}{1+\sigma}) = 0 .$$

Here e^1_{FH} denotes the value of e_{FH} in point I^1_{FH}. The first term in square brackets refers to the marginal spillover gain to country H from widening the financing interval and the second is the above-mentioned substitution effect on country F's own environmental investment. The third term presents the additional spillover gain accruing to H through the income effect influencing F, i.e. it describes the effect (13) on the environment of H. Note that the income effect works so that F increases its environmental investment from the Nash equilibrium onwards. The last term describes the marginal cost of the environmental financing to country H, as presented in (14).[10)]

A similar kind of expression as (17) also holds for the starting point I^0_F of the interval concerned. From these we may first infer the obvious fact that $e^0_{FH} = e^1_{FH}$.

For a given r we may derive from expression (17) two criteria for the spillover yield e_{FH} on those environmental projects that H wants to finance in F. First, H may decide to finance the same projects as the neighbour would like to carry out with its own savings and the substitution effect in (17) is minus unity. In this case in general the requirement for the minimum feasible e_{FH} easily becomes very high.

The case where country H wants to finance additional projects which F would not decide to carry out on its own resources, is more plausible and we only consider this situation. Now in (16) there is no substitution effect and the investment criterium with a given r is

$$(18) \qquad e^0_{FH} \geq e^N_{HH}\left(1-\frac{1+r}{1+\sigma}\right) - e^N_{FH}\mu_F\left(\frac{e^0_{FF}}{e^N_{FF}} - \frac{1+r}{1+\sigma}\right).$$

With r equal to minus unity we have a pure gift, or forgiving debt owed by country F to country H which in our framework may also be called a debt-for-nature swap. In this case we have

$$(19) \qquad e^0_{FH} \geq e^N_{HH} - e^N_{FH}\mu_F\frac{e^0_{FF}}{e^N_{FF}}.$$

A positive income effect μ_F lowers the investment criteria for the international environmental financing to be less than that on the domestic projects. A positive interest rate lowers the required spillover yield e_{FH} in (19), as is natural.

4. Evaluation of the selective environmental financing

By substituting F's constraint (16) for the interest rate on the environmental financing into H's investment criterium (18) we may derive the following expression for the yield of the environmental investment carried out in F and financed by H,

$$(20) \qquad \frac{e^{0}_{FF}}{e^{N}_{FF}} + \frac{e^{0}_{FH}}{e^{N}_{HH}} \geq 1 + (\delta+\alpha)(1-\mu_F\frac{e^{N}_{FH}}{e^{N}_{HH}}) \quad .$$

It is straightforward to use the result (5a) to see that the global optimality condition (10a) is equivalent with (20) when there is unity on the right-hand side of (20). The left-hand side is thus the global yield of the environmental investment carried out in country F, i.e. its yield to F added to its spillover yield to H, measured in terms of the respective consumption prices of the environment. Note that the Nash equilibrium satisfies the condition (20), as is natural, because the value of the left hand side is now two.

The last term in brackets on the right-hand side in (20) is normally positive as μ_F is taken to be less than unity and as e^{N}_{FH} is usually not so much bigger than e^{N}_{HH} to make the product term equal to unity. This implies that we do not expect too many environmental projects to be realized with a small return under the selective environmental financing scheme.

As mentioned above, in a full cooperative solution for the environmental protection the countries agree to carry out all the projects which satisfy the condition (10a) and the respective condition applying to environmental projects in country H. A symmetric Nash bargaining solution would then imply that they decide to share equally the net benefit or surplus related to the cooperation between them and a transfer is then carried out in such a way to achieve this. Analogously, if the countries instead engage in environmental cooperation on a projectwise basis we may imagine that they decide to share equally the net benefit of each project realized in country F.

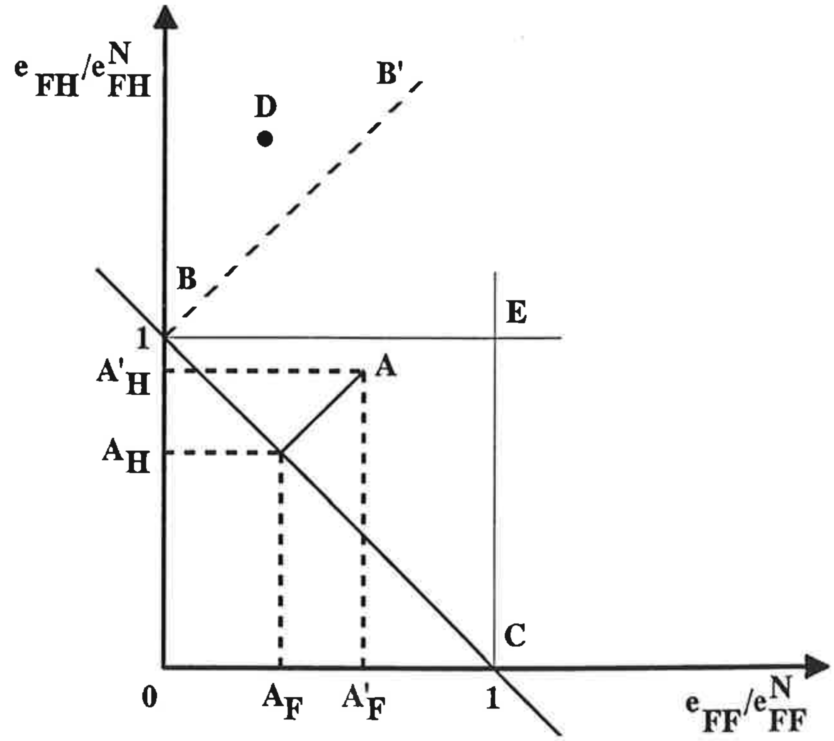
The situation is illustrated in figure 2. A project like that described by point A yields a global surplus presented by its distance from the line BC which presents the minimum global yield required from a unit of environmental investment, see expression (20). The countries are able to share equally the surplus of the project A by means of soft lending in such a way that H finances the project and per unit of investment F pays on it interest and amortization the interval OA_F. The net gain to F is then equal to the interval $A_FA'_F$ and to H the interval $A_HA'_H$.

In practice the factor related to the income effect μ_H in (20) is very small and does not lead to a marked divergence from the first best situation. However, equal sharing of the net benefit may lead to practical difficulties related to certain projects. Those projects like point D which are situated in the area above the line BB' would require more than 100 per cent gift from H to F, i.e. the interest factor $(1+r)/(1+\sigma)$ would be outright negative because the point A_F would now be on the negative side. This may be difficult to be accepted by country H. But in practice we are just likely to encounter a situation, where the projects interesting most H with a spillover yield e_{FH} higher than e^N_{HH} and which the recipient F does not want to realize on its own resources, are situated in the area above (and under) the line BB'.

We also find that pure gifts (when r= -1), if uniformly applied, do not produce an efficient situation as this leads to realization of projects with a global yield (20) higher than unity. This can be seen by writing the condition (17) in a similar form as (20). Now the global yield of these projects is always higher than unity, if $\mu_F e^N_{FH}/e^N_{HH} \leq 1$, which should be the case in practice. So, there is a minimum yield e_{FH} (which is only slightly less than e^N_{HH}) required by H on these projects, as implied by (19). So, only a small fraction of projects in the triangle BCE can be realized as pure gifts.

The conclusion of our results in this section is that a project-wise approach to environmental cooperation may in principle lead to the first best solution, but there may be difficulties related to its practical implementation. We have also found out that the terms on the environmental financing may be quite essential as to the outcome of the cooperation. This we are going to study next with a numerical illustration.

Figure 2. Decentralized realization of the environmental cooperation through equal sharing of the surplus of a project.



5. A numerical illustration

Let us illustrate with a numerical example the results obtained above concerning the gains from international environmental financing. The production functions of the improved environment are specified in the standard way,

$$(21) \qquad E_{ij} = a_{ij}(I_i^E)^{b_{ij}}, \quad 0 \leq b_{ij} \leq 1 .$$

Let us further assume as a simplification that in country i the economies of scale parameters with respect to environment in both countries i and j are the same, i.e. that $b_{ij} = b_{ii}$, and which are denoted by b_i in the following. This means that the marginal international spillover productivities of the environmental investments obey the same internal order as their national productivity. This should well hold in the simplified case when the polluters are concentrated on a single location in both countries. We further assume that the welfare functions (4) are of the simple Cobb-Douglas form,

$$(22) \qquad U_i = E_i^{\alpha_i} C_i^{\beta_i} D_i^{\Gamma_i} \quad \text{with } \alpha_i, \beta_i, \Gamma_i > 0 \text{ and } \alpha_i + \beta_i + \Gamma_i = 1.$$

Now it is straigthforward to derive the optimal allocations for material and environmental investment and present consumption under the noncooperative Nash solution. We get the result that, with some approximation, the present consumption and the environmental investment are linear functions of the initial resources W_i (with a positive coefficient) and of the environmental investment of the neighbour country (with a negative coefficient).

Even though these expressions are interesting per se, we go on to an empirical calculation concerning the welfare of country H by specifying the parameters in the functions (21) and (22). Especially, we are interested to see how big the gains may be from international environmental cooperation and how these depend on the productivity b_H of the environmental investment in country H.

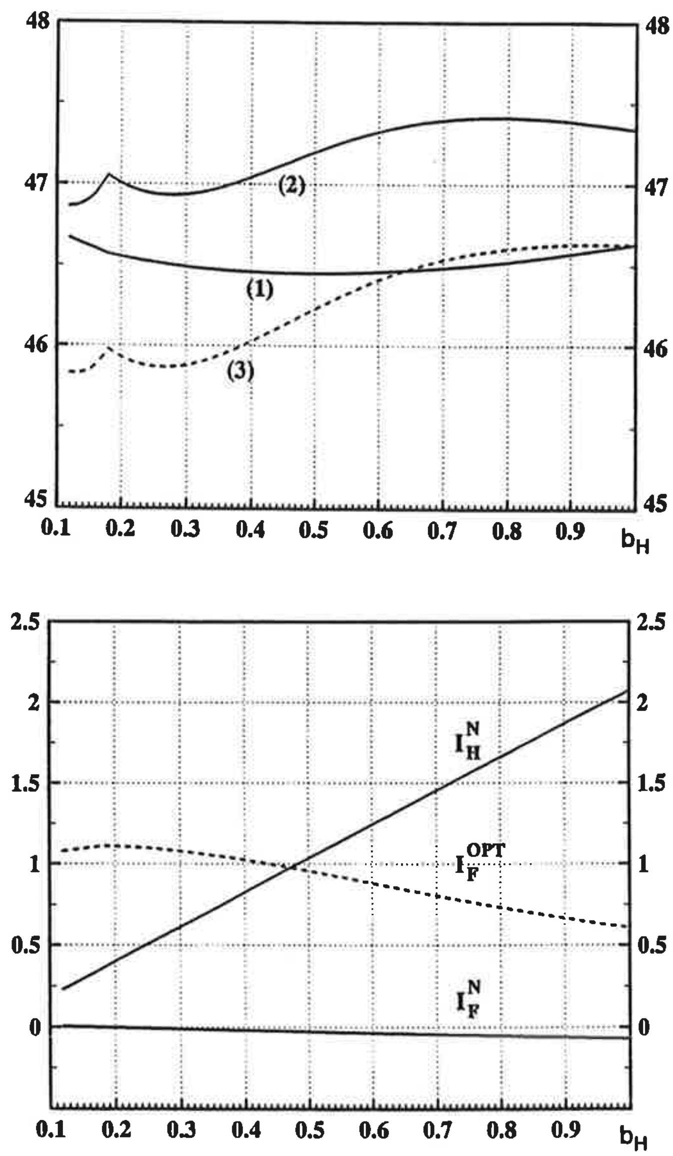
We set the scale so that the initial resources (less the return from material investment) of H and F are 100 and 10 units, respectively. In the Nash equilibrium under constant returns to scale the countries invest the share α_i of their resources in the environment. Evidence from developed countries, including Finland, suggests that at most a couple per cent of GDP is used for environmental needs, hence we calibrate the α_H parameter to be 0.02.[11] For country F we have arbitrarily set the corresponding parameter to be ten times smaller, α_F=0.002. The parameters of the preferences of current and future consumption are the same, $\beta_H=\Gamma_H=0.49$. This implies that the volume of consumption grows at the rate of the time preference which is set at 3 per cent.

The a_{ij}-parameters in (21) are fixed so that the price (U'_{EH}/U'_{CH}) of the environment in country H is unity under the constant returns to scale solution under autarky. This is just a scaling assumption and has no influence on the results. The spillover parameters a_{FH} and a_{FH} and the a_{FF}-parameter are then calibrated in relation to this using the empirical results presented by Kaitala, Pohjola and Tahvonen (1990) to correspond to the situation in suplphur emissions and depositions between Finland and the neighbouring parts of the Soviet Union. Their results imply that the productivity of the environmental investment with respect to the own environment is some five times higher in the Soviet Union than in Finland. The deposition in Finland from a unit of emission in the nearby Soviet Union is estimated to be 20 per cent from that of an unit of emission in Finland. Combining these facts gives the result that a_{FH}, which is under constant returns to scale the cross average productivity of F's investment with respect to H's environment, is some 20 per cent higher than the own productivity a_{HH}.[12)]

Note that in the Nash equilibrium the interaction of the environmental investments between the two countries, which changes as the productivity b_H varies, is taken into account. The scale parameter b_F is fixed throughout somewhat arbitrarily at 0.7. Figure 3 shows that under the Nash equilibrium the welfare of country H is a U shaped function of the b_H-parameter. This is not a necessity, the welfare may also be monotonously rising. In the lower panel of the figure we have depicted the environmental investments. As the productivity b_H rises, the environmental investment by H also rise, as is plausible. The environmental investment in country F are throughout nonexistent in the Nash equilibrium. (Due to the linear approximation they are here in fact slightly negative).

Next, the level of environmental investment in F consistent with the selective unilateral environmental financing scheme analyzed in section 3 is solved from condition (20) (or 10b)). The price of the environment in terms of future consumption is fixed at the level of the Nash equilibrium and it is allowed to change in H when the parameter b_H varies. The increased environmental spillover gains to the welfare of H and the maximum interest charged by H on its environmental financing, which leave F at the welfare of the Nash equilibrium (see (16)), are then added to the welfare of H in the Nash equilibrium.[13] Figure 3 shows that country H may increase its welfare by turning to finance environmental investment in its neighbour on the order of one per cent which may look quite small,

Figure 3. **Upper panel.** The welfare of country H in the Nash equilibrium as a function of the scale parameter b_H (1), when the global optimal amount of environmental investment is carried out in country F and H collects the maximum interest on its financing so that the welfare of F does not rise (2), and the increase in welfare when H collects no interest on its lending to F (3).
Lower panel. The environmental investment under Nash in H and F and the globally optimal investment (opt) in F.



but we have to take into account that the total contribution of the environmental investment to the welfare of country H is on the order of only two per cent.

The globally efficient environmental investment in country F are also depicted in figure 3. They reach a maximum when b_H is around 0.2. This causes the local maximum in the welfare in the upper panel. The optimal environmental investment to be carried out in F are with low values of b_H higher than H's own investment and the situation is reversed when b_H rises towards unity.

In figure 3 we have also depicted the case when country H does not collect any interest from F on the additional investment in F, i.e. H finances them by gifts (swaps of the debt-for-nature type).[14)] We find that in this numerical illustration the maximum interest payment (see footnote (13)) which leaves country F at the same welfare as in the Nash equilibrium make virtually all of the welfare contribution of international environmental financing to H. We can also see that sharing of the net benefits would increase the welfare of both countries, if the productivity b_H is not less than, say 0.4 in this numerical specification.

It should be emphasized that the welfare gains very sensitively depend on the numerical values of the parameters, as is plausible, especially on how much the preferences are directed toward the environment, the relative productivities and also the scales, i.e. the sizes of the countries. Figure 3 is just an illustration with, however, some empirical grounds. So, we may conclude that the terms on the environmental loans are in quite an important position in shaping international environmental cooperation based on unilateral financing operations and the outcome of them for the partner countries. The situation may become even more important if the scope of this kind of cooperation is widened.

6. Conclusions

One basic feature of the analysis above is that we wanted to suggest a more general approach to the environmental cooperation problem than the solutions based on models operating with homogeneous national units, which imply that each environmental measure taken by a country has identical marginal spillover effects to another country. This may hold as a good approximation in the case of countries of a fairly similar small size, but not in the case of a small nation, as the Nordic countries, and a very big neighbouring country like the Soviet Union, when the different environmental projects carried out in the latter country have markedly different outcome on the former depending on where the projects are located.

These fundamentally geographical conditions are a basic consideration why countries might be willing to consider environmental cooperation to be organized along the lines analyzed in the paper. This is also caused by the fact that uniform international agreements on emissions may not be specific enough. Our numerical illustration suggested that financing of environment in the polluting countries on soft terms may considerably increase the welfare of the victim countries. The terms on international environmental financing are an important factor in this context and outright gifts or debt-for-nature swaps do not lead to the first best situation as too few projects are carried out then.

We have analyzed environmental cooperation and its financing in the case of two countries. If two countries engage in environmental cooperation there is a free rider problem because some other countries benefit from the increased environmental protection of these two countries. Therefore, there should be international financing agencies like the Nordic environment financing corporation to take care of the sharing of the burdens of the environment financing between many lender countries.[15)]

All dynamic factors were omitted in the above analysis. So we did not consider the possibility where a country may pursue excessively materialistic policies in order to get the other countries to pay for its bad environment.[16)] The noncooperative environmental financing scheme may lure the debtor country to these kinds of policies, as there are no binding quantitative conditions related to its own environment policies.

Another limitation of this analysis is that all through the paper we assumed full information on technologies and preferences, which is not the case in practice. We should also allow for distortions in the sense that the debtor country may not be integrated in the world financial markets in the way treated above, and may have a higher preference for the present consumption than it should.

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Footnotes

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1) According to the full cooperative solution produced by Mäler (1989), the Soviet Union would cut its sulphur emissions only by 2 per cent as compared to the noncooperative Nash equilibrium, i.e. the situation prevailing in 1984. However, the corresponding cut (with 1987 as the starting point) related to the above-mentioned regional agreement is 42 per cent, as derived by Kaitala, Pohjola and Tahvonen (1990).

2) There may be inherited debt and assets, the amortization of and interest payments on which would then be included in the budget constraints as exogenous items. However, we can combine them with initial resources and operate solely with the net lending L_i variable. Note that we do not consider secondary market quotations on the debt and changes in it as a result of the environmental financing operations as there is no market for financial assets in the model. See on this the analysis of developing countries debt reduction by Helpman (1989).

3) In investment analysis the various projects are arranged in the order of descending marginal productivity from the investor's point of view. Here the e_{ii}-functions describe in this way from a national point of view the productivity of each nation's own environmental investments. The e_{ij}-function, however, describes the yield to the neighbouring country from investment by country i, arranged in the above-mentioned internal order of country i, not j.

4) In the specification of (1) and (2) we do not either explicitly allow for the (normally negative) environmental spillover effects of material investment. This could be done with the cost of a more complicated analysis, but we may with some loss of generality assume that the national environmental consequences of the material investments are already taken into account in the F-function. The material investments also have some (normally negative) international spillover effects on the environment of the other country, but we omit this basically dynamic enlargement in the present study.

5) See Newbery (1990) on decentralization of national environmental policies.

6) Of course the other allocations, too, depend on the the environmental investment by country F, see on this our numerical analysis in section 5.

7) Regarding the various possibilities for the equilibrium, see

an analogous analysis by Hoel (1989).

8) The indifference curves of country H in this plane of environmental investments are presented by the differentials

$$\left(\frac{dI_F}{dI_H}\right)_H = - \frac{U'_{EH}e_{HH} - U'_{CH}}{U'_{EH}e_{FH}} .$$

9) Hoel (1989) has studied altruism in international environmental cooperation.

10) The transfer also potentially gives rise to terms-of-trade effects which are disregarded in our model, as well as possibly to Keynesian type of additional multiplier effects on the production in both countries which we also omit here. Similarly, the possible effects on the prices, e.g. the marginal rates of substitution, are not considered in the present paper.

11) Helsingin Sanomat on January 11,1991 reviewed a fresh study by the US Environment Protection Agency producing this estimate and also referred to similar figures for the Netherlands and Finland.

12) The papers analyzing cooperation in the acid rain game use cost minization instead of our framework of welfare maximizing environmental investment. Therefore, we may shortly present the relation of these two equivalent approaches. Let Q be the deposition and M the emissions. Then we can write

$$e_{ij} = \frac{dE_j}{dI_i} = - \frac{dQ_j}{dI_i} = \frac{dQ_j}{dM_i} \frac{-dM_i}{dI_i} .$$

The first term in the last expression is the element (i,j) in the emission-deposition matrix and the inverse of the second term is the negative of the marginal cost C' of abatement of emissions.

13) The increase in the welfare of H is

$$dU_H = U'_{EH}[E_{FH}(I_F^{opt})-E_{FH}(I_F^N)] + U'_{CH}[(1/e^N_{FF})(E_{FF}(I_F^{opt})-E_{FF}(I^N_F))]$$
$$- U'_{CH}(I_F^{opt}-I_F^N) .$$

The first term is the welfare of the increased environmental spillovers, the second the interest and amortization on the loans (see (16)) and the third the burden of financing additional environmental investments in F.

14) Note that the projects to be realized in F are those related to the global optimum, and not those consistent with the investment criterium (19).

15) See on this the analysis by Newbery (1990).

16) See Ng (1983) on this in connection of a general externality in welfare economics.

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