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## On international compensations for environmental stocks

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# Kieler Arbeitspapiere

# Kiel Working Papers

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**ON INTERNATIONAL COMPENSATIONS  
FOR ENVIRONMENTAL STOCKS**

by Frank Stähler

June 1993



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**Abstract:** This paper sheds some light on the possible implications of compensations which are paid for the maintenance of an environmental stock. It shows that serious complications can arise if the resource-owner can vary the compensation price. In that case, extraction-driven stock preservation policies can conflict with compensation-driven ones and imply instability. Whether compensation policies can neglect this aspect depends crucially on the credibility of sticky compensation prices (*JEL Classification:* D 43, Q 20).

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## 1. Introduction

This paper sheds some light on the possible implications of compensations which are paid for the maintenance of an environmental stock. International compensations for environmental purposes are still in their infancies and the resources devoted to encourage the protection of globally beneficial environmental resources are restricted on project support. But this project support is criticized as an insufficient and inefficient instrument to avoid environmentally harmful repercussions of resource extractions. In addition to the well-known arguments for the need of North-South-compensations, compensations for mere preservation seem to gain increasing political support because they can seemingly guarantee preservation in a very cost-effective manner.<sup>1</sup>

This paper will demonstrate that the optimism surrounding these approaches is far from convincing when compensations are paid for the maintenance of environmental stocks and the donors are not able to stick credibly to a constant compensation price. Without claiming to cover all scenarios of international compensation policies, I will discuss severe complications which are closely related to monopolistic pricing margins of resource-owners. Because preserving globally beneficial environmental stocks is basically a matter of long-run policies, the paper addresses stability aspects more explicitly than static approaches do. The models which I use in this paper are fairly simple and employ optimal control theory. The paper is organized as follows. Section 2 demonstrates the superiority of steady payments in a static setting. Section 3 compares the optimal policies of a resource-owning country without and with a constant compensation price paid per maintained unit of stock. Section 4 addresses compensation policies when the compensation price is not fixed but can be varied by the resource owner. Section 5 concludes the paper.

This paper concentrates on aspects of compensation policies on the policies of resource-owning countries. It neglects aspects of fund-raising and assumes that the benefiting countries are willing to endow a specific environmental fund or that an international environmental agency is able to tax these countries. Although the already existing Global Environmental Facilities give some evidence that the benefiting countries are prepared to pay for preservation, the need for a rapidly increasing budget for compensation purposes increases the incentives to ride free. However, strategic aspects of fund-raising are beyond the scope of this paper.

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<sup>1</sup> For a thorough discussion of financial instruments, see NUNNENKAMP (1992) and the quoted literature there.

## 2. Compensations and Sovereignty Constraints

The agents who receive compensations in an international setting are sovereign countries. If compensations are paid in advance, no authority is able to enforce the agreed-upon environmental services for which the compensations are paid.<sup>2</sup> Consequently, no country is able to commit itself credibly not to breach an international environmental contract. Because both donor and receiver anticipate this institutional deficiency, the sovereignty constraint demands the contract to be self-enforcing, i.e. the receiver must be not worse off by sticking to the agreement than by breaching it. In a world of certainty, this condition can only be met if the compensation game is repeated infinitely.<sup>3</sup>

The large body of literature (e.g. FRIEDMAN, 1971, FUDENBERG, MASKIN, 1986) justifies to adopt a very simple approach here in order to stress the basic idea of steady compensations. Assume that a donor exhibits a willingness-to-pay  $q$  per unit of environmental services. Let  $S$  denote these services which originate from the corresponding preservation which surmounts the receiver's voluntary efforts. The receiver has to decide whether she will stick to the agreement and carry the extra costs  $C(\sigma)$ ,  $C(0)=0$ ,  $C_\sigma$ ,  $C_{\sigma\sigma} > 0$ , or whether she will breach the contract immediately after she has received the compensations. The donor punishes a contract breach by offering compensations never again. The time which elapses between potential offers is denoted by  $h$  and future benefits and costs are discounted by the annual discount rate  $r$ . Any contract which lays  $\sigma'$  down has to satisfy the compliance constraint

$$(1) \quad \sum_{n=1}^{\infty} \frac{q\sigma' - C(\sigma')}{[1+r]^{nh}} = \frac{q\sigma' - C(\sigma')}{[1+r]^h - 1} \geq C(\sigma')$$

The LHS of (1) mirrors the net benefits from sticking to the agreement which consist of the periodical benefits beginning one period later ( $q\sigma'$  is paid anyway in the first period). Hence, the discounted future benefits must not fall short from the instantaneous cost savings  $C(\sigma')$  of the non-compliance option. (1) potentially restricts the joint maximization of benefits

$$(2) \quad \max_S [qS - C(S)] \quad \text{s.t. (1).}$$

<sup>2</sup> See for the basic dilemma of self-enforcing international environmental agreements BARRETT (1992).

<sup>3</sup> According to KREPS, MILGROM, ROBERTS, WILSON (1982), information asymmetries can be helpful to set the stage for temporary cooperation in a finitely repeated game.

According to the Kuhn-Tucker-Theorem with  $\lambda$  as the (non-negative) shadow price of (1), I obtain the solution

$$(3) \quad \begin{aligned} q - C_S(\sigma^*) + \lambda \left\{ \frac{q - C_S(\sigma^*)}{[1+r]^h - 1} - C_S(\sigma^*) \right\} &= 0 \\ \lambda \geq 0, \frac{q\sigma^* - C(\sigma^*)}{[1+r]^h - 1} - C(\sigma^*) \geq 0, \lambda \left\{ \frac{q\sigma^* - C(\sigma^*)}{[1+r]^h - 1} - C(\sigma^*) \right\} &= 0, \end{aligned}$$

If the compliance constraint does not bind, i.e.  $\lambda = 0$  for the unconstrained optimal  $\sigma$ , full cooperation will emerge. But if  $r$  is high enough, both face a positive  $\lambda$ . Because (2) is concave in  $\sigma$ , they can try to find a lower positive preservation level which just meets the compliance constraint.

If  $h$  is not fixed, the compliance constraint never applies through a sufficient reduction of  $h$ . An  $h$  approaching zero lets the compliance constraint vanish because the payment occurs at the very moment of the fulfilment of the contract. Hence, paying steadily provides us with an option which avoids severe compliance problems.<sup>4</sup> If the donator is able to monitor the degree of environmental services instantaneously, even an explicit contract is superfluous. From this perspective, all the donator needs is an account number, a sufficient monitoring technique and a consistent pricing rule. The need for a monitoring technique does not raise serious problems because modern satellite techniques are very successful in monitoring even very small-scale outdoor regions. E.g., the verification of the size of tropical forests and the evaluation of corresponding stock-dependent payments seems to be a comparably easy task. It is these stock-dependent services and two sets of pricing rules on which I focus in the remainder.

### 3. The Basic Model of Compensating for Environmental Stocks

The resource-owner is assumed to derive utility from a global environmental stock only via extractions, i.e. the environmental stock services accrue solely to the donator. Let  $B$  denote the net benefits from extractions  $E$ ,

<sup>4</sup> Steady payments are not the only instrument available to achieve stable international environmental agreements. E.g., MOHR and THOMAS (1993) discuss the stabilizing effect of cross-default clauses between environmental and credit contacts. STÄHLER (1992) discusses the stabilizing role of in-kind-transfers to compensate non-compliant agents.

$$(4) \quad B(t) = B[E(t)], B_E > 0, B_{EE} < 0, B_{EEE} = 0, \lim_{E \rightarrow 0} B_E < \infty.^5$$

The resource owner faces positive, marginally decreasing net benefits from extractions. Extractions are neither necessary nor essential resource inputs into production which induces non-infinite marginal net benefits. The environmental resource is exhaustible and renewable which is mirrored by the regeneration function which depends on the stock:

$$(5) \quad R(t) = R[S(t)] \quad 0 < S' < S^0 : R(S) > 0, R_{SS} < 0$$

$$S \begin{cases} = 0 \\ > S^0 \end{cases} : R(S) = 0$$

$$0 < S \leq S^{MY} : R_S \geq 0, \lim_{S \rightarrow 0^+} R_S(S) = \infty$$

$$S^{MY} < S \leq S^0 : R_S < 0, \lim_{S \rightarrow S^{0-}} R_S(S) \geq -\infty$$

(5) defines a fairly convenient regeneration function.<sup>6</sup> Assuming an infinite limit for a stock approaching zero ensures that every real positive number can be assigned to the first derivative of a stock which belongs to the range of positive regeneration. Due to the assumption of no directly stock-dependent benefits, the dynamic problem resembles the one of optimal fishery (see CLARK, 1976, DASGUPTA, HEAL, 1979). Assume that the planning horizon is infinite and that the resource-owner discounts the future by the time-invariant discount rate  $r$ . Without compensations, the maximization problem of a resource-owning country is given by

$$(6) \quad \max \int_0^{\infty} e^{-rt} B(t) dt \quad \text{s.t.} \quad \dot{S} = R(t) - E(t)$$

<sup>5</sup>  $B_{EEE} = 0$  is only met by a quadratic benefit function and shows up as a convenient assumption for the stability of the solution in this section's model. See footnote 8. Partial differentiations are denoted by a respective subscript whereas differentiations with respect to time are denoted by a dot. Throughout the paper, I suppress the time index whenever suitable.

<sup>6</sup> Especially the infinite limit of the marginal regeneration for the zero stock will show up to save an interior solution even if the discount rate is very high. Note that a conventional logistic function cannot catch the corresponding properties of the regeneration function because it assumes a finite limit for the zero stock. To present an example, the simple circle function (defined for a positive  $R(S)$  only)

$$R(S) = \sqrt{[S^{MY}]^2 - [S - S^{MY}]^2}, R_S = -\frac{S - S^{MY}}{R(S)}, R_{SS} = -\frac{1}{R(S)} - \frac{[S - S^{MY}]^2}{[R(S)]^3} < 0$$

produces infinite limits for  $S = 0$  and  $S = S^0$ . Note also that the second derivative of this function is indeed negative, whereas the third derivative can be shown to depend on the stock.

and the respective initial stock. The corresponding current-value Hamiltonian  $H_c$  is given by

$$(7) \quad H_c = B(t) + \lambda(t)\{R(t) - E(t)\}$$

Rewriting the optimality condition and substituting for the costate variable gives

$$(8) \quad B_{EE} \dot{E} = B_E [r - R_S]$$

(9) describes the steady state which is reached when the discount rate and the marginal regeneration equalize:<sup>7</sup>

$$\begin{aligned} \dot{E} = \frac{B_E [r - R_S]}{B_{EE}} &= 0 = \varepsilon(E, S) \\ (9) \quad \Leftrightarrow r = R_S \\ \dot{S} = R(t) - E(t) &= 0 = \sigma(E, S) \end{aligned}$$

$\varepsilon$  and  $\sigma$  describe the implicit functions for the steady state equations. Partial differentiation of  $\varepsilon$  gives the infinite slope of the  $\varepsilon$ -function

$$\left. \begin{aligned} \varepsilon_E = r - R_S \\ \varepsilon_S = -\frac{B_E R_{SS}}{B_{EE}} \langle 0 \rangle \end{aligned} \right\} \Rightarrow \begin{cases} \lim_{r \rightarrow R_S^+} \left. \frac{dE}{dS} \right|_{\dot{E}=0} = -\infty \\ \lim_{r \rightarrow R_S^-} \left. \frac{dE}{dS} \right|_{\dot{E}=0} = +\infty \end{cases}$$

The partial derivatives of  $\sigma$ , i.e.

$$\sigma_E = -1$$

$$\sigma_S = R_S$$

complete the definition of the Jacobi matrix  $J$  and allow for the local stability analysis. The trace and the determinant of  $J$ ,

$$tr(J) = r, |J| = -\frac{B_E R_{SS}}{B_{EE}} \langle 0, [tr(J)]^2 \rangle 4|J|.$$

show that the steady state is a saddle point. Figure 1 reveals the stable branches on which a convergence to the steady state is guaranteed. Because there is no restriction

<sup>7</sup> The infinitely positive limit of the zero stock ensures an interior solution. If instead  $\lim_{S \rightarrow 0^+} R_S(S) = i < \infty$  holds, the resource will be completely extinct if  $r > i$ .



on  $E$  which means that  $E$  can jump on a stable branch immediately, the potential instability of the saddle point does not impose a serious problem. For any given initial stock, there exists exactly one extraction level to start with which lies on the "yellow brick road" to the steady state.

<Figure 1 about here>

Now assume that a donator exists who is willing to pay  $Q[S(t)]$  for the preservation of the stock from which he benefits by the arising global environmental services. The steady stream of payments  $Q[S(t)]$  changes the benefits of the receiver which now also depend on the stock. Hence, he optimizes according to

$$(10) \quad \max \int_0^{\infty} e^{-rt} \{B(t) + Q[S(t)]\} dt \quad \text{s.t.} \quad \dot{S} = R(S) - E(t).$$

The corresponding Hamiltonian is given by

$$(11) \quad H_c = B(t) + Q[S(t)] + \mu(t)\{R(t) - E(t)\}.$$

Applying the Maximum Principle demands the Arrow Sufficiency Condition to be fulfilled:

$$(12) \quad \frac{\partial^2 H_c}{\partial S^2} = Q_{SS} + B_E R_{SS} \leq 0$$

I will assume that (12) will always hold. It can be easily demonstrated, however, that compensating for the provision of a necessary or even essential environmental resource can induce corner solution if  $Q[S(t)]$  mirrors the marginal willingness-to-pay. Whether compensation policies aim at tackling a problem of an essential or necessary environmental resource stock depends crucially on the availability of a backstop technology (NORDHAUS, 1973). If substitution of the stock services is possible for finite costs, I can assume without significant loss of generality that the condition spelled out in (12) is valid in the whole relevant range. After rewriting the optimality conditions and substituting for the costate variable, I obtain

$$(13) \quad B_{EE} \dot{E} = B_E [r - R_S] - Q_S.$$

This section focuses on a constant compensation price  $q$  which is paid per unit of stock and which the donator does not modify after compensations are introduced. The donator is assumed to stick credibly to this constant price forever. For this set of

compensation policies,  $Q_S$  is simply given by the constant compensation price  $q$  and demands for the change of extractions

$$(14) \quad B_{EE} \dot{E} = B_E [r - R_S] - q.$$

(15) describes the steady state:

$$\dot{E} = \frac{B_E [r - R_S] - q}{B_{EE}} = 0 = \varepsilon^*(E, S)$$

$$(15) \quad \Leftrightarrow r - \frac{q}{B_E} = R_S$$

$$\dot{S} = R(t) - E(t) = 0 = \sigma^*(E, S)$$

Partial differentiation reveals the positive inclination of the  $\varepsilon^*$ -curve:

$$\left. \begin{array}{l} \varepsilon_E^* = r - R_S = \frac{q}{B_E} > 0 \\ \varepsilon_S^* = -\frac{B_E R_{SS}}{B_{EE}} < 0 \end{array} \right\} \Rightarrow \frac{dE}{dS} \Big|_{\dot{E}=0} = \frac{B_E R_{SS}}{B_{EE} [r - R_S]} > 0, \quad \frac{d^2 E}{dS^2} \Big|_{\dot{E}=0} = \frac{B_E R_{SSS} [r - R_S] + B_{EE} R_{SS}}{B_{EE} [r - R_S]^2}$$

When  $E$  approaches zero, a zero change in extractions is guaranteed according to (14) by an  $R_S$  which falls short from  $r$  as long as  $B_E(E=0) < \infty$ . Hence, the isocline  $\dot{E} = 0$  starts on the RHS of the old one and increases in  $E$  as  $S$  increases. Due to the ambiguous sign of  $R_{SSS}$  (see Footnote 6), nothing is known about the concrete curvature on purely theoretical grounds. The local stability analysis of the corresponding Jacobi matrix reveals a positive trace of  $J$  but the evaluation of the determinant's sign seems to be ambiguous, therefore signalling potential local instability:

$$tr(J) = r, |J| = [r - R_S] R_S - \frac{B_E R_{SS}}{B_{EE}}$$

However, it is easily demonstrated that the saddle point attributes remain valid. A positive determinant  $|J|$  which would induce global instability demands a positive  $R_S$  at the equilibrium. Hence, instability should be given if

$$R_S > \frac{B_E R_{SS}}{B_{EE} [r - R_S]} = \frac{dE}{dS} \Big|_{\dot{E}=0}$$

This instability condition conflicts with the path properties which I have derived above because a concave regeneration function cannot intersect an always increasing function at a point of larger inclination when the other function starts on the RHS of the regeneration function.<sup>8</sup> Figure 2 shows the phase diagram for a policy which aims at a long-run preservation of a stock that produces a negative marginal regeneration.

<Figure 2 about here>

This result could be rather helpful for politicians because the preservation of any stock belonging to the range of positive regeneration can be obtained in the long run.

#### 4. A Price Adjustment Model of Compensating for Environmental Stocks

Section 3 assumed that the donator is a Stackelberg leader who sticks credibly to a constant compensation price  $q$ . To suppose a donator who is able to create such a commitment machine which works infinitely is no weak assumption. If the donator is not able to introduce such a rigid compensation mechanism, resource-owners will take into account that their stock decisions are able to vary the compensation price. Observing that the resource-owning countries are often only few in number justifies an approach which takes imperfections into account.

Consider the resource owner which knows that her stock decisions vary the compensations according to

$$(16) \quad q(t)S(t) = [a - bS(t)]S(t), \quad S^{\max} = \frac{a}{b}.$$

<sup>8</sup> Now it is evident that  $B_{EEE} = 0$  is a very convenient assumption for the stability of this problem because it guarantees an always positive  $\epsilon_E^* = r - R_S$ . If  $B_{EEE} > 0$ ,  $\epsilon_E^*$  must be supplemented by

$$\frac{B_{EEE} \{ B_E [r - R_S] - q \}}{B_{EE}^2}$$

This term causes ambiguity with respect to the sign of  $\epsilon_E^*$  except in a sufficiently narrow neighborhood around  $\epsilon^*$  where the term vanishes due to the optimality condition. Hence, a non-zero  $B_{EEE}$  does not endanger local stability but global one because stable branches may not exist when the agent is far away from the steady state.

<sup>9</sup> Alternatively, one could model oligopolistic interactions more explicitly by considering  $n$  identical countries. In that case, the compensation price would be given by

$$q(t) = \alpha - \beta \sum_{i=1}^n S^i(t).$$

But the reinterpretation of several regeneration functions is not straightforward and one has to take possible collusion among resource owners into account, too. Hence, this section

(16) sets the stage for the other set of compensation policies which may be based on an international institution like a supranational environmental agency which, e.g., compensates the resource-owners on the basis of marginal utilities.<sup>10</sup> It could be imagined as possessing tax-raising power to cover its expenses. This approach may mirror reality more appropriately than Section 3's model because it can approximate the institutional setting of an environmental fund whose members reevaluate the success and the "appropriate" compensation price periodically according to (16).<sup>11</sup> The parameter  $a$  can be considered as a proxy for the costs of the backstop technology which defines the reservation price for compensations. The parameter  $b$  determines the degree of "stickiness" which is felt by the resource owner. The lower  $b$ , the higher is the effect of the stock size on the compensation price.

The maximization problem changes for the resource-owner into

$$(17) \quad \max \int_0^{\infty} e^{-rt} \{U(t) + [a - bS(t)]S(t)\} dt \quad \text{s.t.} \quad \dot{S} = R(S) - E(t),$$

and the respective initial stock. The new Hamiltonian is given by

$$(18) \quad H_c = B(t) + [a - bS(t)]S(t) + \gamma(t)\{R(S) - E(t)\}.$$

Rewriting the optimality condition and substituting for the costate variable gives

$$(19) \quad B_{EE} \dot{E} = B_E [r - R_S] - [a - 2bS].$$

The steady state conditions are

$$(20) \quad \begin{aligned} \dot{E} &= \frac{B_E [r - R_S] - [a - 2bS]}{B_{EE}} = 0 \\ \dot{S} &= R(t) - E(t) = 0 \end{aligned}$$

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concentrates on the same resource owner and the compensation function should be regarded as a perceived demand function of this resource owner. This perceived demand function can mirror Cournot oligopoly or collusion.

<sup>10</sup> Whether these utilities are Lindahl-based or imperfect marginal willingness-to-pay-measures is not considered here.

<sup>11</sup> The assumption of discrete jumps merely complicates the analysis and does not add new insights. Unless the receiving countries can manipulate the jump by additional means besides their stock decisions, the problem remains the same in qualitative terms. See for the role of jumps in optimal control theory SEIERSTAD, SYDSAETER (1987).

Now, equalizing  $B_E[r - R_S]$  and  $a - 2bS$  is much more complex than in the case of fixed prices because the stock does not only enter the regeneration function but the marginal compensations as well. Evaluating the first and second derivative of the corresponding  $\dot{E}$ -function gives

$$(21) \quad \left. \frac{dE}{dS} \right|_{\dot{E}=0} = \frac{B_E R_{SS} - 2b}{B_{EE}[r - R_S]}$$

$$\left. \frac{d^2 E}{dS^2} \right|_{\dot{E}=0} = \frac{B_E R_{SSS}[r - R_S] + R_{SS}[B_E R_{SS} - 2b]}{B_{EE}[r - R_S]^2}$$

If  $r - R_S$  is positive for the whole relevant range, imperfections imply a mere decrease in services as one expects from static models, too. One could tolerate this deviation as an unavoidable imperfection which is accepted as the performance of many industrial markets, too. But the positive sign of  $r - R_S$  is not guaranteed. Let  $\hat{S}$  stand for the stock that meets the  $\dot{E} = 0$ -curve at an extraction level of zero.  $\hat{S}$  is implicitly defined by

$$(22) \quad [r - R_S(\hat{S})]B_E(0) = a - 2b\hat{S}.$$

To balance both terms,  $\hat{S}$  is not limited to produce only a positive  $r - R_S$ . The sign of the LHS of (22) is determined by the marginal biological regeneration and the discount rate which define the net interest. The RHS displays the conventional marginal yield which arises in a competitively imperfect environment. If

$$(23) \quad R_S(\hat{S})r \Leftrightarrow a - 2b\hat{S} < 0$$

holds, equalizing both terms leads to negative signs. In this case, (21) induces a negative slope of the isocline. Hence, (23) is a necessary and sufficient condition for a negatively sloped  $\dot{E} = 0$ -curve.

Before addressing stability aspects, some economics on this point are helpful. If (23) is valid, the resource owner has to operate in a range of stocks which conflicts with her conventional monopolistic plans. To meet the steady state condition (20), she must supply a stock which is beyond her maximum yield. Her discount factor and the biology induce her to aim at a stock which lies in the range of a perceived demand elasticity which surmounts -1. From the perspective of compensations, she should keep a lower stock, but from the perspective of her extraction policy, she should keep a higher one. This shows that market imperfections can set incentives to hold a lower stock than a resource-owner would like to hold voluntarily.

The RHS of (23) reflects the marginal yield of the resource owner and the LHS can be considered as her marginal costs which are due to the net interest weighted by the marginal benefits of extractions. If (23) applies, the resource owner must outweigh the marginal costs and the marginal yields in the *negative* domain. The net interest of the stock which is determined by the discount rate and the biology of the resource does not fit in with the exploitation of the donator's willingness-to-pay. Hence, imperfections can produce an obviously unstable steady state which falls short from the voluntary one.

Writing (26) as an implicit function,

$$(28) \quad \rho(a, b, r, \hat{S}) = [r - R_S(\hat{S})]B_E(0) - a + 2b\hat{S} = 0,$$

allows for investigating the effects of the parameters on  $\hat{S}$ :

$$(29) \quad \left. \begin{array}{l} \rho_a = -1 \\ \rho_b = 2\hat{S} > 0 \\ \rho_{\hat{S}} = -R_{SS}(\hat{S})B_E(0) + 2b > 0 \\ \rho_r = B_E(0) > 0 \end{array} \right\} \Rightarrow \begin{array}{l} \frac{\partial \hat{S}}{\partial a} > 0 \\ \frac{\partial \hat{S}}{\partial b} < 0 \\ \frac{\partial \hat{S}}{\partial r} < 0 \end{array}$$

First, the higher the reservation price, i.e. the higher the costs of substituting the environmental resource completely, the higher is the steady-state-stock which determines a negative marginal yield. This condition may be not obvious in contemporary approaches which rely on a low compensation price level and trap into rising prices only very slowly. Second, it is not amazing that a large  $b$  increases the chances of a stable steady state because a  $b$  approaching infinity changes the demand curve into an horizontal line of fixed prices. Third, it seems surprising that a low discount rate increases the chances of a stock which meets condition (27). But (27) is only fulfilled if the exploitation of imperfections demands a stock which falls short from the voluntary one. Therefore, a lower discount rate increases the voluntary steady state stock and thereby increases the chances of instability.

The phase diagram of dominant imperfections is given in Figure 3. It demonstrates the instability which accompanies (27). According to (25) and the assumptions of (5), the  $\varepsilon$ -function can possess an inflection point and must exhibit an infinitely negative slope when the stock approaches zero. Additionally, one can easily show that  $\pi(J) = r, |J| > 0$  holds. I refrain from interpreting the phase diagram extensively because no degree of extractions exists which leads to the steady state for any given initial stock. The

resource-owner is inevitably entrapped into an insolvable conflict which cannot be cured on the decision basis which this model has assumed.

<Figure 3 about here>

This section has shown that imperfections do not merely lead to a lower degree of environmental services. Moreover, they are likely to induce serious compatibility problems between the extraction-driven and the compensation-driven stock policies. Neglecting the issue of imperfections and relying on a sufficient workability of compensation policies could therefore result in severe complications if the reservation price is very high and the resource owners are more patient than expected. Hence, committing absolutely credibly to a fixed compensation price policy turns out as a crucial prerequisite to compensate successfully for the maintenance of a stock which produces environmental services.

## 5. Conclusions

This paper has questioned the advantages of compensating for global environmental services on a steady basis when compensations try to maintain an environmental stock. It has shown that serious complications can arise if the resource-owning countries are few in number and the reservation price of the donor is very high. In that case, extraction-driven stock preservation policies can conflict with compensation-driven ones. This feature may be non-observable today but can turn out as a severe complication in managing globally beneficial resource stocks in the long run. Whether compensation policies can neglect this aspect depends crucially on the credibility of sticky compensation prices. Hence, the design of international organizations is not merely a subordinate matter but decides crucially on the long-run success of monetary compensation policies. Any institutional deficiency of organizing compensations may endanger the success and even the stability of international environmental policies. But whether the donors can credibly stick to a fixed compensation price is not only a matter of the institutional setting but depends basically on the donors' intertemporal performance. If the donors are represented by the countries' governments, the agents reevaluating compensation policies change in the course of time. This change renders a credible commitment more difficult.<sup>12</sup>

When the institutional design of compensation policies calls for sophisticated mechanisms, project support may be a good alternative when preservation policies is felt as an urgent task. Project support ensures a direct control of the donor on the use

<sup>12</sup> See for the decisive role of a player's attributes GÜTH (1990).

of a part of the environmental resource. E.g., project support financed by the World Bank or the Global Environmental Facilities implies the management of the resource use by the donator. Where compensations leave the property rights untouched, project support changes the ownership structure. Hence, project support can compensate its higher administrative costs by directly saving an essential part of the resource for the donator and providing compensations for resource-owning countries. Thus, project support may be at least a good starting point for international environmental policies.



## 6. References

- Barrett, S. (1992), *Self-Enforcing International Agreements*, mimeo, London Business School.
- Clark, C.W. (1976), *Mathematical Bioeconomics: The Optimal Management of Renewable Resources*, Wiley: London.
- Dasgupta, P.S., Heal, G.M. (1979), *Economic Theory and Exhaustible Resources*, Cambridge University Press: Cambridge.
- Friedman, J. (1971), *A Noncooperative Equilibrium for Supergames*, Review of Economic Studies, 38: 1-12.
- Fudenberg, D., Maskin, E. (1986), *The Folk Theorem in Repeated Games with Discounting or with Incomplete Information*, Econometrica, 54: 533-554.
- Güth, W. (1990), *Game Theory's Basic Question: Who is a Player?*, mimeo.
- Kreps, D., Milgrom, P., Roberts, J., Wilson, R. (1982), *Rational Cooperation in the Finitely Repeated Prisoners' Dilemma*, Journal of Economic Theory, 27: 245-252.
- Mohr, E., Thomas, J., (1993), *Pooling Sovereignty Risks: The Case of Environmental Treaties and International Debt*, Kiel Working Paper No. 568, The Kiel Institute of World Economics.
- Nordhaus, W.D. (1973), *The Allocation of Energy Resources*, Brookings Papers on Economic Activity, 3: 529-570.
- Nunnenkamp, P. (1992), *International Financing of Environmental Protection. North-South Conflicts on Concepts and Financial Instruments and Possible Solutions*, Kiel Working Paper No. 512, The Kiel Institute of World Economics.
- Seierstad, A., Sydsaeter, K. (1987), *Optimal Control Theory with Economic Applications*, North-Holland: Amsterdam.
- Stähler, F. (1992), *Pareto Improvements by In-Kind-Transfers*, Kiel Working Paper No. 541, The Kiel Institute of World Economics.

Figure 1: Base Case without Compensations

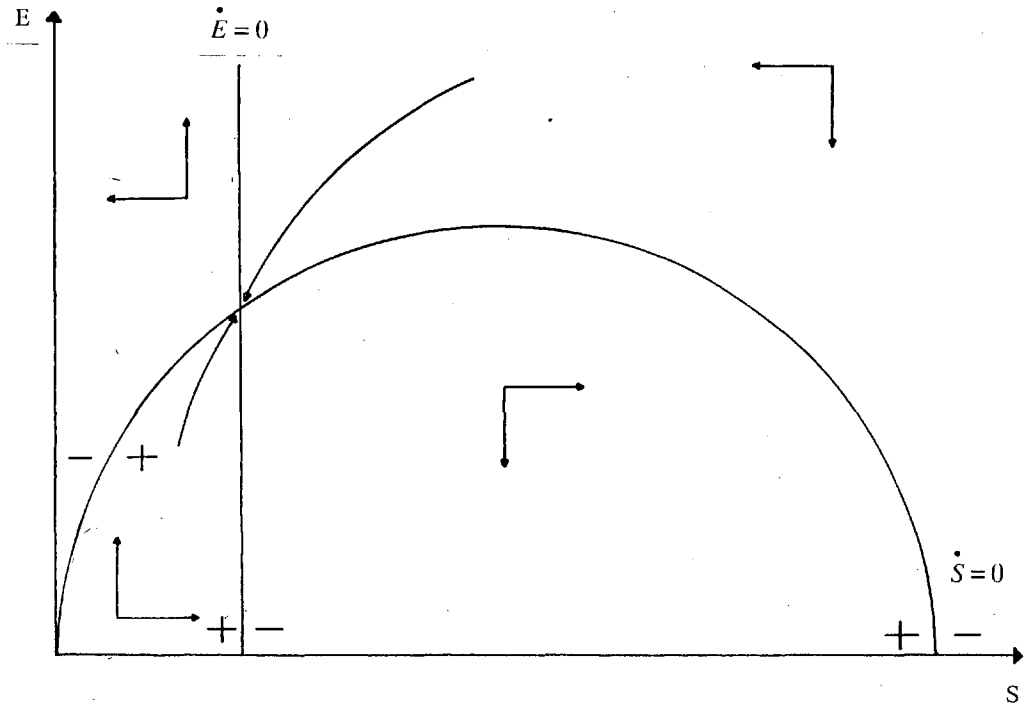


Figure 2: The Intertemporal Adjustment in the Case of a Fixed Compensation Price

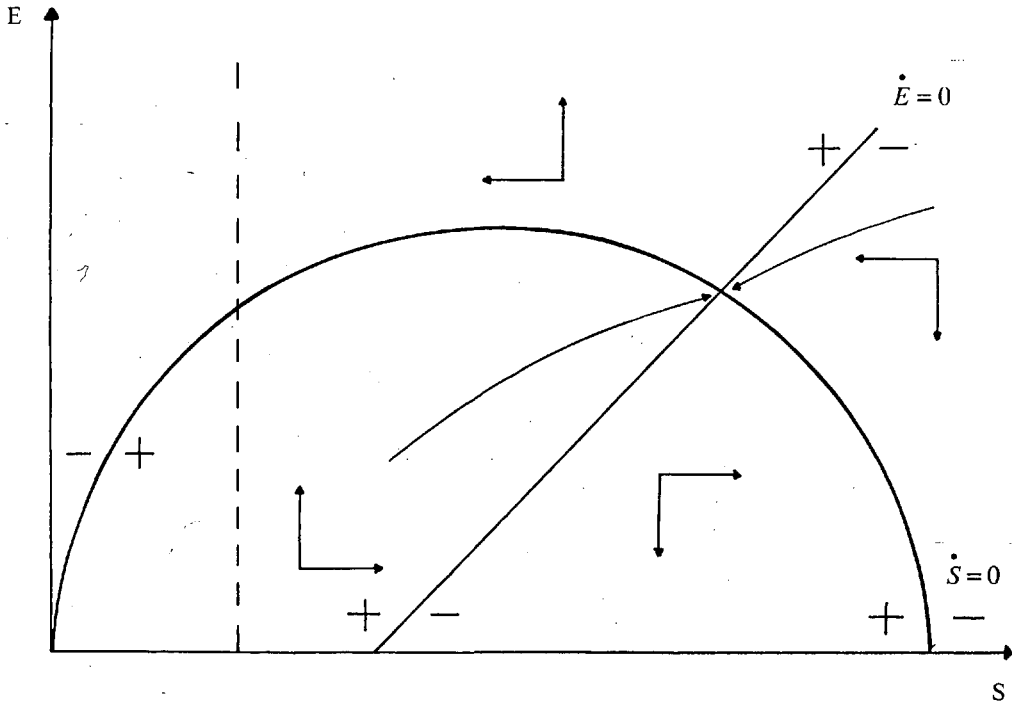


Figure 3: The Intertemporal Adjustment in the Case of a Variable Compensation Price and Dominant Imperfections

