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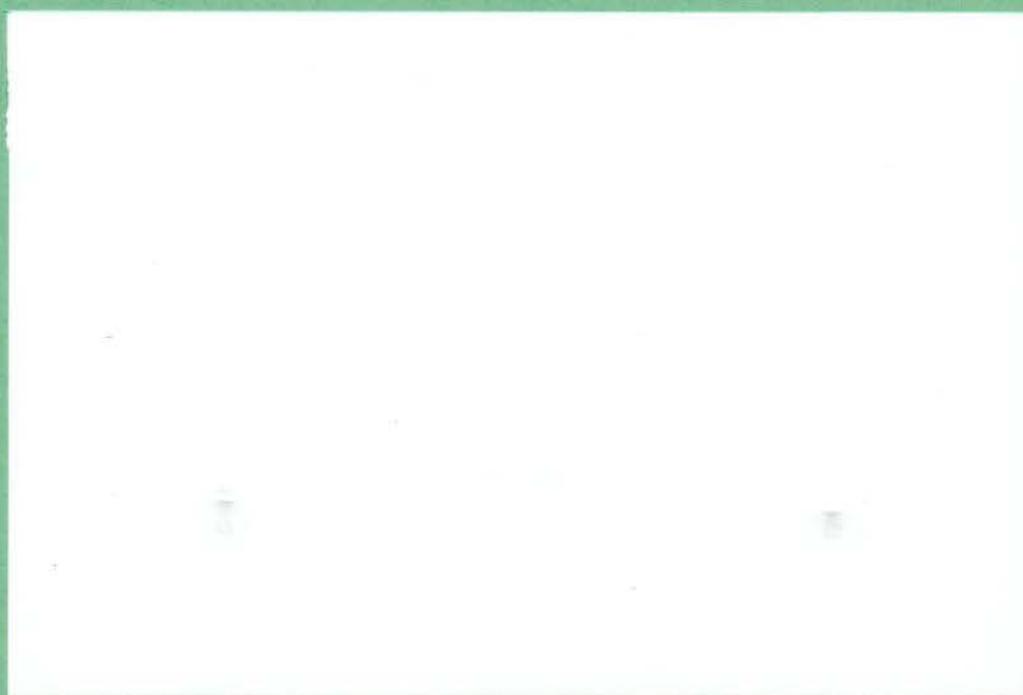
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**UNIVERSITÄT - GESAMTHOCHSCHULE - SIEGEN
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INTERNATIONAL ENVIRONMENTAL POLICY AND ENFORCEMENT DEFICITS

Rüdiger Pethig

Diskussionsbeitrag Nr. 17-90

Abstract:

Incomplete enforcement of environmental laws and regulations does not seem to be a transitory phenomenon. Enforcement deficits may arise because polluters are reluctant to comply but also because the monitoring agency prefers pleasant working conditions to rigorous enforcement effort. In this paper, incomplete implementation of environmental rules is explained by the interaction between the goal-setting government and its monitoring agency. First a simple model is set up for a closed economy. Then this approach is extended to the situation of two countries which are interrelated by (reciprocal) transfrontier pollution. By juxtaposing non-cooperative and cooperative behavior it is possible to assess the allocative impact of cooperation - including the implied changes in national monitoring efforts and enforcement deficits. The final section addresses the issue of the distribution of gains from cooperation with reference to the polluter-pays principle.

International Environmental Policy and Enforcement Deficits

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1. Introduction

In the literature on environmental economics and administrative science and likewise in public opinion the introduction of environmental standards by law or government directive is very often considered to imply an immediate and complete transformation of the status quo into the intended improvement of environmental quality. In recent years much evidence accumulated, however, pointing to considerable slippage between the lips of the legislator who aims at pleasing the electorate and the flow of environmental benefits from the government's cup.²

One might argue that incomplete implementation is a transitory phenomenon of adjustment following the introduction of the piece of legislation under scrutiny. But empirical observations e.g. of Hansmeyer (1989), Hucke, Müller, and Wassen (1983) or Mayntz (1978) suggest that the enforcement deficits in environmental policy seem to be persistent so that they should be considered and analysed as a phenomenon of equilibrium rather than one of adjustment towards complete enforcement.

It is also true, of course, that implementation problems are not only akin to environmental policy. On the contrary, they are very wide-spread if not ubiquitous, since "delinquents" can safely be expected to emerge whenever a piece of legislature passes the parliament. Not all enforcement deficits have the same empirical

¹I am grateful to Wolf Ekkehard Seiler for checking the algebra. He is not responsible for any remaining errors, of course.

²This metaphor is used by Mueller (1979, p. 148) in a somewhat different context.

significance, however. Certainly it makes sense to disregard implementation issues in many cases as a satisfactory approximation. But in Germany as in other countries the incompleteness or even failure of enforcing the existing environmental regulations seems to have become a decisive issue in recent time. Hansmeyer (1989, p.75) considers the notion of "enforcement deficit" - in German "Vollzugsdefizit" - a much conjured catch-word.

In view of such a diagnosis economic theorists should feel challenged to focus attention on this issue. There is a branch of implementation analysis with a long tradition and solid foundation in social sciences. But to my knowledge it does not rely very much on economic tools. On the other hand there was and is a strong tendency in the literature of environmental economics to proceed in its analysis on the assumption of perfect monitoring and/or compliance³ But for economists who believe in the agents' self-interest as the driving force in all regulatory games this perfectness proposition ought to be dismissed. In recent years increasing attention has been drawn to the monitoring and enforcement issue (Downing 1981; Downing and Hanf 1983; Russell et al. 1986; Harford 1987; Meyer-Renschhausen 1988; Russell 1990; Jones and Scotchmer 1990; Ströbele 1990) but much more needs to be done both on the theoretical and empirical level.

Starting with the idea of self-interested agents in a game of environmental regulation the major focal point is naturally placed on the regulatee or polluters. Rather than seeing them as voluntarily complying to the rules in order to further the common good many economists prefer to view them as acting and reacting in the spirit of Becker's (1965) "crime and punishment" paradigm. This line of argument known from many areas of regulation will not be explicitly pursued in what follows. We rather wish to focus attention to another slippage between legislation and imple-

³In an attempt to identify the reasons for neglecting the issue of monitoring and enforcement Russell (1991) observes that regulations are designed and legislated at the highly visible central level whereas the task of monitoring is delegated to peripheral units. He also argues that the analysis of monitoring and enforcement issues is probably considered by academics both unglamorous and technically difficult.

mentation which emerges because chief administrators do not use to implement in person regulatory rules but very often delegate that task to some peripheral agent. Due to imperfect information on the side of the principal the agent (or agency) has some discretion in doing the job. When in addition the agent is a self-interested person whose objectives do not coincide with the principal's orders, we are bound to end up with a game of incomplete enforcement.

The central approach of explaining incomplete enforcement consistently as a result of the interaction between the goal-setting government and an environmental protection agency is, of course the agency theory. At its core is the assumption of incomplete and asymmetric information which generates discretion for the self-interested agent. This property clearly makes agency theory very realistic and attractive, but it also causes complexity and hence problems of manageability.

For that reason the present paper compromises on the informational aspects of the enforcement issue by developing a simple deterministic principal-agent approach to environmental management which is then extended to international environmental policy and cooperation in the presence of transfrontier pollution. Section 2 sets up the model for a single economy and Section 3 extends that approach to the scenario of two countries which are interrelated by (reciprocal) transfrontier pollution. By juxtaposing non-cooperative behavior and international cooperation the allocative impact of the latter is assessed. The final Section 4 proceeds by discussing the distribution of the gains from cooperation with reference to the polluter-pays principle.

2. Environmental Management. in the Absence of Transfrontier Pollution

Consider a partial equilibrium model of an economy in which the total emission flow of pollutants per period is assumed to be $E_0 > 0$ when no environmental controls are enforced. The government adopts some environmental policy from a set of policy tools, it

fixes an emission standard $S < E_0$ in order to signal to the electorate that it pursues a goal-oriented environmental management, and it delegates to its environmental protection agency the task of implementing that policy with the government-determined budget B . The agency expands that budget for administrative work and enforcement activities to reduce the emission flow from its laissez-faire value E_0 to

$$(1) \quad E = E_0 - p I B \geq 0 \quad (p > 0).$$

As shown in (1) the extent of emission reduction not only depends on the size of the budget but also on the policy-specific "productivity coefficient" p (policy tool effectiveness) and the agency's own working intensity or enforcement effort, I . To interpret this variable look at implementation as a complex process of bargaining in which many parties are involved and in which the agency has to deal with polluters (firms, households, other government agencies), with courts and with special interest groups. In an attempt to gain some "leisure on the job" its members are inclined to "soft" and low-effort enforcement postponing or avoiding all those cases where they expect severe resistance of polluters or other parties. Such a strategy presupposes, of course, some discretion of the agency vis-a-vis its supervisor, the government. An alternative interpretation of the variable I - not incompatible with the preceding description - is to look at I as a fraction of the budget so that $(1-I)B$ is easily identified as the agency's discretionary budget used for management slack reminiscent of Williamson (1964).

While the environmental protection agency's only decision variable is its implementation effort I , the government has at its disposal the following three policy parameters all of which exert significant influence on the agency's performance:

- (i) it assigns an amount of resources, the budget B , to the agency;
- (ii) it fixes an emission standard $S \in [0, E_0]$ to be implemented by the agency;

- (iii) in case of an enforcement deficit it puts pressure on the agency to reduce that gap by increasing its monitoring effort M .

The agency's objective function is

$$(2) \quad A(I; E, M, S) = -\frac{1}{2} \mu M \cdot (E - S)^2 - i I \quad (i, \mu > 0).$$

According to (2) the agency suffers from high levels of working intensity ($i > 0$) but it is willing to undertake efforts towards implementation of the emission standard S , because in case of an enforcement deficit ($E - S > 0$) the agency is exposed to pressure from its supervisor which grows more than proportionally with the widening of the gap. Moreover, increasing M and μ implies the agency receiving even greater negative sanctions for any given implementation gap. While M is a continuous decision variable, the coefficient μ indicates the institutional or organisational efficacy per unit of monitoring effort M .

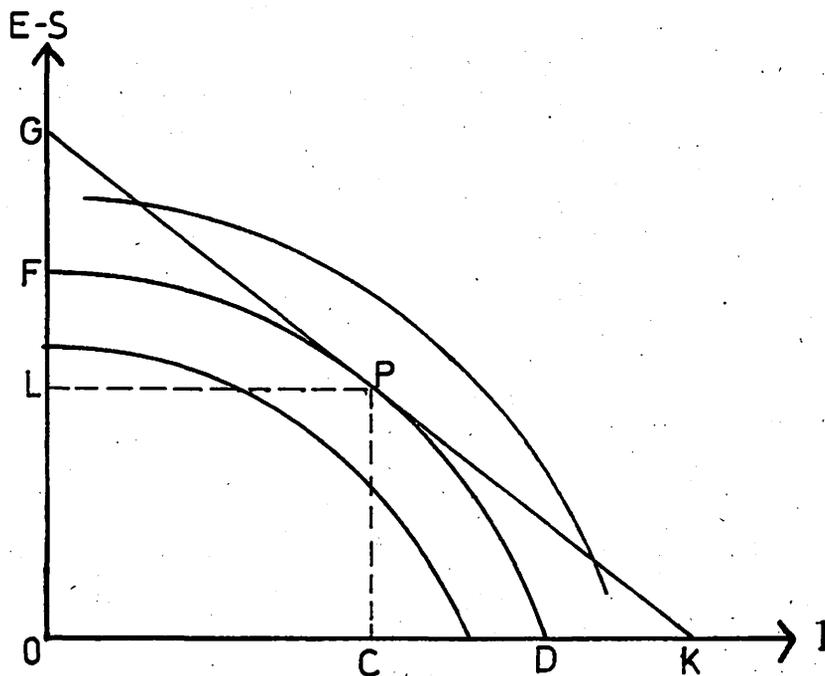


Figure 1: The agency's optimal decision

In view of (1) the agency maximises (2) over I for predetermined activities of the government B , M and $S > 0$. The straightforward solution is

$$(3) \quad E = S + \frac{i}{\mu p B M} \quad \text{and} \quad I = \frac{(E_0 - S) \mu p B M - i}{\mu p^2 B^2 M}.$$

Figure 1 illustrates the agency's decision problem. The indifference curves such as FD are strictly concave with increasing levels of satisfaction towards the origin. The "budget line" is derived by writing (1) as $E - S = (E_0 - S) - pBI$. Hence $OG = E_0 - S$ and $OK = (E_0 - S)/pB$, and it is clear that the agency chooses point P with the coordinates OL and OC as specified in (3). Observe that owing to the quasi-linearity of function (4) the agency's optimal implementation deficit is independent of standard S (no "income effect").

Obviously, the enforcement deficit $E - S = i/\mu p B M > 0$ is the smaller

- the less the agency suffers from its own enforcement effort (small i);
- the more effective are the policy tools chosen (large p);
- the greater is the government's monitoring effectiveness and monitoring effort (large μ and large M);
- the larger is the agency's budget (large B).

The enforcement deficit clearly emerges because the agency derives satisfaction from shirking. But as demonstrated above its width depends also on the government's decisions on B , M and S . The government sets these variables as to maximise its objective function

$$(4) \quad G(B, E, M, Q, S) = q Q - s S - \frac{1}{2} \cdot \left(\frac{E}{e+1} - S \right)^2 - b B - m M$$

with $b, e, m, q > 0$ and $s \geq 0$. In (4) the letter Q represents an index of ambient environmental quality assuming that decreasing emission flows translate into increasing sustainable levels of

environmental quality according to the simple transformation

$$(5) \quad Q = Q_0 - E.$$

The interpretation of qQ in (4) is that voters honor the government's commitment to high environmental quality ($G_Q = q > 0$). Voters are also assumed to respond positively to the government's announcement of ambitious environmental policy goals in form of restrictive emission standards ($s > 0$). In view of (5) one has $qQ = qQ_0 - qE$, so that the government is punished by the electorate not only by establishing a lax emission standard ($s > 0$), but also by tolerating a high flow of emission ($G_Q Q_E = -q < 0$). The third term on the RHS of (4) specifies the citizen-voters' discontent with enforcement deficits. The smaller is the parameter e , the more aware are the citizens of the enforcement deficits and push for better performance of the government⁴. Technically speaking, $e > 0$ ensures to turn the emission standard into a well-defined endogenous policy variable. Note that $e = 0$ would imply $S = 0$.

The government's aim to keep the agency's budget low ($G_B > 0$) can be rationalised by arguing that there are always competing uses for tax money within the government, that citizens resist to paying taxes, and that according to (1) the budget is used to reduce the emission of pollutants which in turn is costly to entrepreneurs and triggers their opposition. Finally, the government dislikes high levels of monitoring effort ($G_M < 0$) for similar reasons why the agency prefers low levels of enforcement effort.⁵

⁴Hansmeyer (1989, p. 74) argues that citizens suffer from an "implementation illusion" buoying them up with the vain hope that tighter emission standards (written on a piece of paper) lead automatically to an improvement of the ambient environmental quality. To consider this effect one might introduce an additional parameter premultiplying the third term on the LHS of equation (4).

⁵Alternatively or complementary, M can be interpreted as extra money to be spent on monitoring activities; with such an interpretation one could set $m = b$ or one could write $(m+b)M$ instead of mM . In what follows we will not pursue that route, however.

We now substitute Q from (5) and S from (3) into (4) to obtain

$$(4') \quad G(B, E, M) = \\ = q Q_0 - (q + s) E + \frac{i s}{\mu p B M} - \frac{1}{2} \cdot \left[\frac{i}{\mu p B M} - \frac{e}{e+1} E \right]^2 - b B - m M.$$

The government maximises (4') with respect to B , M , and E to obtain

$$(6a) \quad B = \frac{m}{b} M = \left[\frac{i m [q (e+1) + s]}{b^2 e \mu p} \right]^{\frac{1}{3}},$$

$$(6b) \quad M = \frac{b}{m} B = \left[\frac{b i [q (e+1) + s]}{e \mu m^2 p} \right]^{\frac{1}{3}},$$

$$(6c) \quad E - S = \left[\frac{b e^2 i m}{\mu p [q (e+1) + s]^2} \right]^{\frac{1}{3}},$$

$$(6d) \quad S = \frac{1}{e} \cdot \left[\frac{b e^2 i m}{\mu p [q (e+1) + s]^2} \right]^{\frac{1}{3}} - \frac{(q+s) (e+1)^2}{e^2},$$

$$(6e) \quad E = Q_0 - Q = \frac{e+1}{e} \cdot \left[\frac{b e^2 i m}{\mu p [q (e+1) + s]^2} \right]^{\frac{1}{3}} - \frac{(q+s) (e+1)^2}{e^2}.$$

The agency's implementation effort turns out to be

$$(7) \quad I = \frac{E_0 - E}{p B} = \\ = \frac{e^2 E_0 + (q+s) (e+1)^2}{e^2} \cdot \left[\frac{b^2 e \mu}{i m p^2 [q (e+1) + s]} \right]^{\frac{1}{3}} - \frac{b (e+1)}{p [q (e+1) + s]}.$$

When the equations (6a), (6b), (6d) and (6e) are considered in (4'), one obtains, after some rearrangement of terms,

$$(8) \quad G = q Q_0 + \frac{(q+s)^2 (e+1)^2}{2 e^2} - 3 \cdot \left[\frac{b i m [q (e+1) + s]}{e \mu p} \right]^{\frac{1}{3}}.$$

Similarly, substituting (6b), (6c), and (7) in (2) results in

$$(9) A = - \frac{i b (3 e + 2)}{2 p [q (e+1) + s]} - \left[E_0 + \frac{(q+s)(e+1)^2}{e^2} \right] \left[\frac{b^2 e i^2 \mu}{m p^2 [q(e+1)+s]} \right]^{\frac{1}{3}}$$

shock response	Δb	Δe	Δi	Δm	$\Delta \mu$	Δp	Δq	Δs
ΔI	?	?	-	-	+	?	?	?
ΔB	-	-	+	+	-	-	+	+
ΔM	+	-	+	-	-	-	+	+
$\Delta E = -\Delta Q$	+	?	+	+	-	-	-	-
$\Delta(E-S)$	+	+	+	+	-	-	-	-
ΔS	+	?	+	+	-	-	-	-
ΔG	-	?	-	-	+	+	?	?
ΔA	-	?	-	+	-	+	?	?

Table 1: Displacement effects of exogenous shocks

Table 1 summarises the impact of parametric changes: It is particularly interesting to observe that increasing policy efficacy ($\Delta p > 0$), increasing weight on a low emission standard and high environmental quality ($\Delta s > 0$ or $\Delta q > 0$), decreasing disutility from effort ($\Delta e < 0$ or $\Delta m < 0$) and decreasing opportunity costs of the agency's budget ($\Delta b < 0$) have the same effect on the formation of the emission standard and on implementation: All these changes lead to a tighter emission standard and to an even greater decrease of the actual emission flow so that the implementation gap becomes smaller. It is remarkable, on the other hand, that their impact on the agency's budget, on implementation effort and monitoring effort is quite divergent.

The role of parameter e is not easy to interpret in light of the reactions to its changes in Table 1. Increasing e broadens the

implementation gap while at the same time the government cuts the agency's budget and reduces its monitoring effort. But the agency also raises its implementation effort so strongly as to make possible a reduction of both the actual emission and the emission standard.

The last two rows of Table 1 show how the government and the agency evaluate parametric changes. They agree on using more effective policy tools ($\Delta p > 0$) and on the detrimental effect of increasing opportunity costs of the agency's budget ($\Delta b > 0$). The government would support the agency's interest for action to cushion its discontent with high enforcement effort ($\Delta i < 0$) but, conversely, the agency is not sympathetic about attempts to reduce the government's opportunity costs from monitoring ($\Delta m < 0$). Observe finally that changes of the parameters e , q and s have no clear-out impact on the government and the agency.

3. Transfrontier Pollution and Cooperation: The Allocative Impact

Now the model is modified by considering two countries, the home country and the foreign country. The variables assigned to the home country and the foreign country are marked by the superscript h and f , respectively. With this qualification the equations (1), (2), (3) and (4) hold for both countries, but (5) is replaced by⁶

$$(10) \quad Q = Q^h = Q^f = Q_0 - E^h - E^f.$$

Since one country's emission affects the objective function of the other country's government via (10), we have, in fact, a

⁶The more general case would be to assume $Q_j = Q_{0j} - \epsilon_{jj}E_j - \epsilon_{kj}E_k$ with $j, k = h, f$, $j \neq k$, and $\epsilon_{jj}, \epsilon_{kj} > 0$. But since we don't intend to focus on ecological asymmetries as indicated by particular values of ϵ_{jj} and ϵ_{kj} the formulation (10) suffices for the subsequent investigations. By writing $Q^h = Q^f$ in (10) the transfrontier pollution problem is strictly reciprocal. Later we will also comment on the case of unilateral pollution.

simple game situation in which emission levels E^j are the strategies and the functions G^j the payoffs.

Assume first that cooperation doesn't take place, i.e. that neither the government nor the agency of any country is able or willing to influence the other country's environmental policy. In such a setting country j 's objective function (payoff) differs from $G(B^j, E^j, M^j)$ in (4') in that for $j, k = f, h, f \neq h$

$$(11) \quad G^j(B^j, E^j, M^j; E^k) = G(B^j, E^j, M^j) - q^j E^k.$$

With Cournot-Nash behavior then the countries simply choose the best response to alternative levels of the other country's emission of pollutants. As is obvious from (11) each country has a dominant strategy.⁷ The associated unique (Nash) equilibrium in dominant strategies exhibits the same values of all variables as in the case of strictly "domestic pollution" except that

$$(12) \quad Q = Q_0 - \sum_{j=f,h} \left\{ (e^{j+1}) \left[\frac{v^j}{[q^j(e^{j+1}) + s^j]^2} \right]^{\frac{1}{3}} + \frac{(q^j + s^j)(e^{j+1})^2}{e^{j2}} \right\},$$

where $v^j := b^j i^j m^j / (e^j \mu^j p^j)$. The parameter v^j captures the impact of five out of the eight national parameters on the equilibrium value of environmental quality. The greater is v^j , the less effective is country j 's institutional setting of its environmental management. For simplicity we refer to v^j as an index of ineffectiveness of environmental management in country j . Using this notion equation (12) states that for given $e^j, q^j, s^j, j = f, h$, the ambient environmental quality is the lower, the less effective are the countries' environmental policies.

To conclude, with non-cooperative Cournot-Nash behavior each

⁷This property is a consequence of the "additive separable nature" of both the relationship between Q and E^j, E^k in (10) and of the governments' objective functions.

country pursues its environmental management as if there were no transfrontier pollution. In particular, both of them disregard the severe reduction of the common environmental quality caused by the other country's emission. It follows that parameter changes for the home and foreign country have the same impact on all variables - including Q - as shown in Table 1.

Suppose now the countries agree to cooperate by choosing their environmental management as to maximise the sum

$$(13) \quad G^h(B^h, E^h, M^h; E^f) + G^f(B^f, E^f, M^f; E^h).$$

For convenience of notation, write $X^j(C)$ with $j = f, h$ for the value of the variable $X = A, B, E, E-S, I, M, S$ in the cooperative solution and $X^j(NC)$ for its value in the non-cooperative dominant strategy equilibrium. It is straightforward from maximizing (13) that for all X the solution value $X^j(C)$ differs from $X^j(NC)$ only in that the parameter q (representing q^h or q^f) from the equations (6), (7), and (9) is substituted by $r := q^h + q^f$ everywhere. With this qualification all displacement effects ΔX caused by a shift from non-cooperation to cooperation are obviously the same in sign as the ratio $\Delta X^j / \Delta q^j$ in Table 1. We conclude, therefore, that for $j = f, h$ one obtains

$$X^j(C) - X^j(NC) < 0 \quad \text{for } X = E, E-S, S,$$

$$X^j(C) - X^j(NC) > 0 \quad \text{for } X = B, M, Q.$$

It is, of course, a well-established result of the literature that cooperation raises environmental quality by reducing both countries' equilibrium flows of emission. But it is not so obvious, as the present model shows, that environmental improvement goes along with increased budgets for implementation (B) and monitoring efforts (M) at the national levels. Moreover, the imple-

⁸This doesn't hold for $G^j(C)$ the discussion of which will be postponed to the next section.

mentation gaps are reduced even though the national emission standards are tightened – implying that the actual emission flows are reduced by more than the emission standards.

To further investigate the allocative impact of the transition to cooperation in international environmental policy, it is also interesting to know how all these displacement effects vary across the two countries. For expository simplicity we restrict the subsequent analysis to the assumption

$$(14) \quad e^f = e^h = 1, s^f = s^h = 0 \text{ and } q^h = q^f > 0.^9$$

Using (14) equation (6e) yields

$$(15) \quad E^j(r) = (2v^j/r^2)^{1/3} - 4r.$$

Clearly, function E^j from (15) is strictly decreasing in r , and we establish for all $r > 0$

$$E^f(r) \geq E^h(r) \Leftrightarrow v^f \geq v^h \text{ and } \frac{d}{dr} [E^f(r) - E^h(r)] \geq 0 \Leftrightarrow v^f \leq v^h.$$

For $q^h = q^f$ these inequalities imply

$$0 < E^f(\text{NC}) - E^f(\text{C}) > E^h(\text{NC}) - E^h(\text{C}) \Leftrightarrow v^f > v^h.$$

Hence in absolute terms the country whose domestic environmental management is less effective reduces its emissions more than the other country. It is easy to check, however, that the elasticity of emissions with respect to r , rE_r^j/E^j , is in the interval $(-1,0)$ and decreasing in v^j . Consequently,

⁹As shown in Table 1, the effects of q and s are qualitatively the same so that the loss of information from ignoring s is small. Choosing the same value of q for both countries means that they are assumed to differ only in their supply-side conditions of environmental quality but not in their demand-oriented "environmental consciousness" (as measured by q). The main reason for fixing e is technical simplification.

$$\frac{E^f(\text{NC}) - E^f(\text{C})}{E^f(\text{NC})} < \frac{E^h(\text{NC}) - E^h(\text{C})}{E^h(\text{NC})} \Leftrightarrow v^f > v^h.$$

It turns out that the relative reduction of the emission flow is greater in that country which has the more effective environmental management even though the reverse is true for the absolute reduction. The changes of domestic emission standards associated to the shift from non-cooperative behavior to cooperation are easily assessed by turning (6d) into

$$(16) \quad S^j(r) = (v^j/2r^2)^{1/3} - 4r.$$

Owing to the great similarity between (16) and (15) it is straightforward that all results derived in the preceding paragraph for changes of emission levels apply also for the emission standard: The country with the less effective environmental management fixes a higher emission standard before and after cooperation than the other country¹⁰. While in absolute terms its drop in emission standard is greater, the relative reduction is smaller than in the country with the more effective environmental management.

We conclude this section by briefly considering the case of unilateral transfrontier pollution. Let the foreign country be located upstream with a constant fraction of its emissions spilling over into the home country so that, with an appropriate normalization, equation (10) is replaced by

$$(17) \quad Q^f = Q_0^f - E^f \quad \text{and} \quad Q^h = Q_0^h - E^h - E^f.$$

The consequences of this modification are straightforward. The non-cooperative equilibrium is analogous to the case of reciprocal transfrontier solution because the home country plays its dominant strategy. Assume then, the foreign country "cooperates" in

¹⁰In other words, even if both countries are alike in terms of pre-policy emission levels ($E_0^f = E_0^h$), cooperation does not imply, in general, that national emission standards ought to be harmonised.

the sense that it changes its domestic environmental management as to maximise (13) with respect to its own decision variables. Then the differences $X^f(C) - X^f(NC)$ are as in the case of reciprocal transfrontier pollution. For the home country $X^h(C) = X^h(NC)$ holds for all X . The essential question is, of course, why the foreign country should change its policy as required for maximisation of (13). This question is not trivial in the case of reciprocal transfrontier pollution, either, because in both settings cooperation might not be achieved if the distribution issue cannot be settled between the governments. The following section takes a closer look at these problems.

4. Distribution of the Gains from Cooperation

Suppose first the countries reach an agreement to cooperate in the sense of maximising (13) without the provision of any compensation payment. With $G^j(C)$ as the payoff in case of cooperation without compensation the inequality $G^f(C) + G^h(C) > G^f(NC) + G^h(NC)$ clearly holds and therefore

$$G^f(C) - G^f(NC) > - [G^h(C) - G^h(NC)].$$

According to this inequality at least one country gains from trade, and at most one country may turn out to be a loser. To see what the equilibrium payoffs $G^j(C)$ and $G^j(NC)$ are like consider, as a first step, (4) and (10):

$$(18) \quad G^j = q^j Q_0 - q^j E^j - q^j E^k - s^j S^j - \frac{1}{2} \left(\frac{E^j}{e^{j+1}} - S^j \right)^2 - b^j B^j - m^j M^j.$$

With $r := q^f + q^h$ and $v^j := \frac{b^j i^j m^j}{e^j \mu^j p^j}$ as already introduced in the

last section one obtains from (6)

$$b^j B^j + m^j M^j = 2b^j B^j = 2[v^j (r(e^{j+1}) + s^j)]^{1/3},$$

$$S^j = E^j - e^j [v^j (r(e^{j+1}) + s^j)^{-2}]^{1/3} \text{ and}$$

$$E^j(r) = [(e^{j+1}) [v^j (r(e^{j+1}) + s^j)^{-2}]^{1/3} - (r+s^j)(e^{j+1})^2/e^{j2}.$$

Substitute these terms into equation (18) to rewrite that equation, after some rearrangement of terms, as

$$(18') \quad G^j(C) = q^j Q_0 + \frac{(r+s^j)^2 (e^{j+1})^2}{2e^{j2}} - 3[v^j (r(e^{j+1}) + s^j)]^{1/3} + q^k E^j(r) - q^j E^k(r) \quad \text{and}$$

$$(18'') \quad G^j(NC) = q^j Q_0 + \frac{(q^j + s^j)^2 (e^{j+1})^2}{2e^{j2}} - 3[v^j (q^j (e^{j+1}) + s^j)]^{1/3} - q^k E^k(q^k).$$

Under the assumption (14), the equations (18') and (18'') are turned into

$$(19) \quad G^j(C, r) = \frac{Q_0}{2} r + 2r^2 - [54v^j r]^{1/3} + D^j(r)$$

$$\text{with } D^j(r) := \Delta v^j r^{1/3} \quad \text{and} \quad \Delta v^j := \left[\frac{v^j}{4}\right]^{1/3} - \left[\frac{v^k}{4}\right]^{1/3};$$

$$(20) \quad G^j(NC, r) = \left(\frac{Q_0}{2} - 2\right)r + \frac{r^2}{2} - 3(v^j r)^{1/3} - (v^k r)^{1/3}.$$

Equation (20) readily yields

$$(21) \quad G^j(NC, r) - G^k(NC, r) = [(v^k)^{1/3} - (v^j)^{1/3}] 2r^{1/3}$$

providing the information that in a non-cooperative situation of reciprocal transfrontier pollution each government has an incentive to improve the effectiveness of its own environmental policy by raising v^j . But it would be reluctant to encourage its neighbor government to do the same.

Subtracting (20) from (19) gives

$$(22) \quad G^j(C,r) - G^j(NC,r) = \frac{3}{2}r^2 + 2r + \\ + [3 + (\frac{1}{4})^{1/3} - 54^{1/3}](v^j r)^{1/3} - [(\frac{1}{4})^{1/3} + 1](v^k r)^{1/3} \\ \approx \frac{3}{2} r^2 + 2r + [0.014(v^j)^{1/3} - 1.794(v^k)^{1/3}] r^{1/3}.$$

Equation (22) shows that government j 's gain from cooperation is the smaller, *ceteris paribus*, the smaller is $r = q^h + q^k$ and the greater is v^k . Government j is, in fact, worse off by cooperation if and only if (approximately)

$$0 < \frac{3}{2} r^{5/3} + 2 r^{2/3} < [1.794(v^k)^{1/3} - 0.014(v^j)^{1/3}]$$

Even though this inequality cannot be readily solved for r , it is clearly the more likely that government j loses from cooperation without compensation the lower is the environmental consciousness (r) in both countries, the less effective is the foreign and the more effective is the own environmental management. Moreover, (22) also yields the conclusion that under assumption (14)

$$0 < G^h(C) - G^h(NC) > G^f(C) - G^f(NC) \Leftrightarrow v^f > v^h$$

In verbal terms, the foreign government gains less than the home government - or even loses - if, *ceteris paribus*, in the foreign country, as compared to the home country,

- public funds for the environmental protection agency have higher opportunity costs ($b^f > b^h$);
- the agency derives more pleasure from shirking ($i^f > i^h$);
- the government has greater dissatisfaction from monitoring ($m^f > m^h$);
- monitoring is less effective ($\mu^f < \mu^h$);
- the environmental policy instruments employed are less effective ($p^f < p^h$).

The preceding results hinge on our interpretation of cooperation as adopting at the national level that environmental management which is necessary to maximise (13) without any compensatory or side payments. But since the government with the more effective policy is the comparative or even absolute loser it lacks any incentive to cooperate in the first place. In fact, whenever the countries differ in policy effectiveness, the burden of cooperative environmental management is not distributed in line with the polluter-pays principle. According to that principle each government j should bear the entire, i.e. both the domestic and foreign, cost of its domestic emission, $q^j E^j + q^k E^j$, but it should not be burdened with $q^k E^k$.

On the other hand, when cooperation does not involve compensation payments, each government bears $q^j E^j$ and $q^k E^k$, but not $q^k E^j$. Hence no-compensation cooperation differs from cooperation with compensation according to the polluter-pays principle in the following way: the former yields the payoffs (18'), the latter requires the government j whose term $q^k(E^j(r) - E^k(r))$ in (18') is positive to transfer the amount $q^k(E^j(r) - E^k(r))$ of money to the other government. It is now important to ask the question how the distribution of gains under cooperation observing the polluter-pays principle is related to policy effectiveness. To provide an answer we refer again to the simplification (14) which turns $q^k(E^j(r) - E^k(r))$ from (18') into $D^j(r)$ as defined in (19). Hence the payoff from cooperation satisfying the polluter-pays principle is $P^j(r) := G^j(C,r) - D^j(r)$. It is easy to verify that the function $P^j(r)$ is strictly convex in r and attains its minimum at $r = [3v^j/4]^{1/5}$. Moreover, one has

$$\text{sign } D_r^j = \text{sign } \Delta v^j \text{ and } \text{sign } D_{rr}^j = (-1) \text{sign } \Delta v^j.$$

Therefore, $G^j(C,r)$ is strictly convex and below $P^j(r)$, if $\Delta v^j < 0$, and it is above $P^j(r)$ (but not necessarily convex), if $\Delta v^j > 0$.

0. Observe first that the case $\Delta v^i = 0$ implies¹¹ $D^j(r) = D^k(r) = 0$ and therefore $G^j(C,r) = P^j(r) = G^k(C,r) = P^k(r)$ with $j \neq k$.

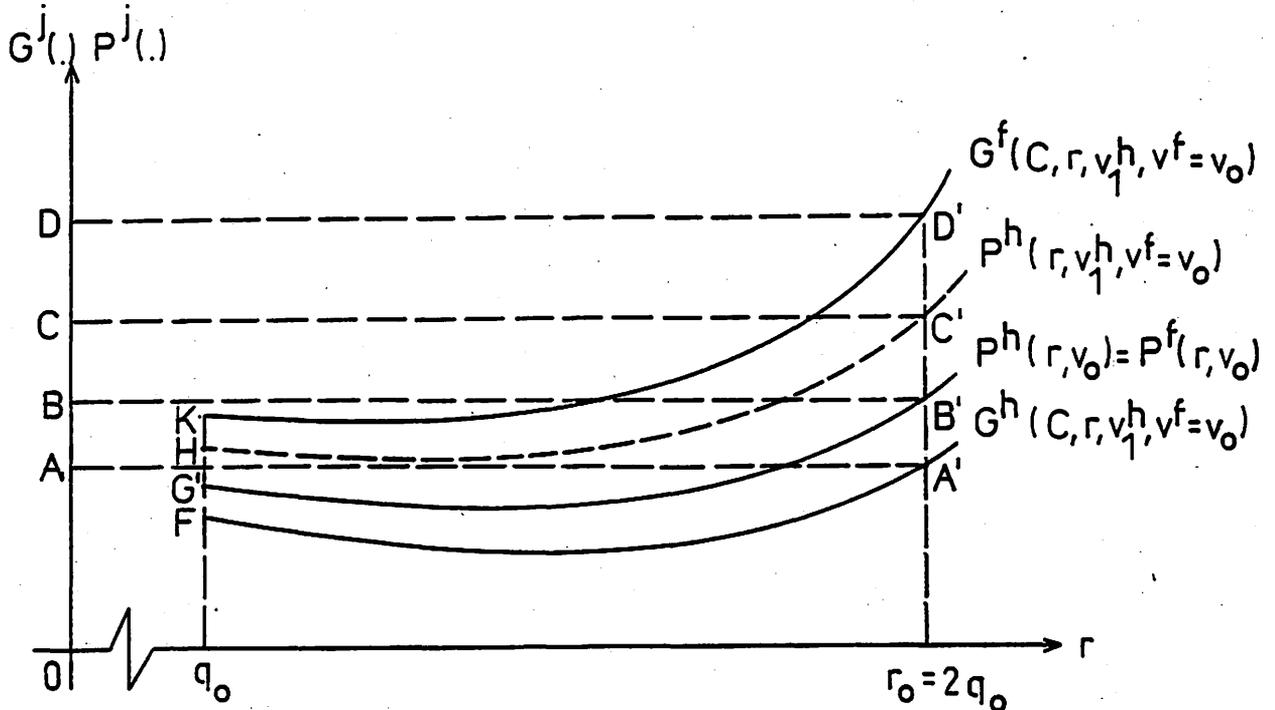


Figure 2: Cooperation with and without compensation payments

This situation is illustrated in Figure 2 for $q^h = q^f = q_0$. The line $\overline{GB'}$ is the graph of (16) if $v^h = v^f = v_0$. Hence OB is both governments' identical payoff when cooperation takes place. In the special case of identical countries the polluter pays principle is satisfied without any compensation payments. Suppose next, that v^h is somehow reduced to $v_0^h < v_0$, but $v^f = v_0$ remains unchanged. This parametric change leaves $P^f(\cdot)$ unchanged ($= \overline{GB'}$) but shifts $P^h(\cdot)$ upward to HC' . It follows that the home country's payoff increases from OB to OC . On the other hand, if cooperation takes place but compensation payments are excluded, the home country reaches point A' on $\overline{FA'}$ whereas the foreign country moves to point D' on $\overline{KD'}$.

¹¹ Δv^j does not necessarily mean that both countries are identical in all aspects.

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