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AN ANALYSIS OF SO_2 NEGOTIATIONS BETWEEN FINLAND AND THE SOVIET UNION****

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ABSTRACT: This paper demonstrates a case for the 'victim pays principle' in Finnish-Soviet environmental cooperation. It is shown that efficient cooperation on reducing sulphur emissions may entail financial transfers from Finland to the Soviet Union because marginal abatement costs are much lower there. Soviet emissions should be drastically reduced in Kola peninsula and Estonia. The analysis is based on a sulphur transportation model, on estimated regional abatement cost functions and on the revealed-preference approach in estimating the damage costs from pollution.

1 Introduction

Acid rain is known to render lakes incapable of supporting aquatic life, to threaten forest and agricultural productivity and to damage statuary and other exposed materials. Airborne concentrations of sulfate particles can — besides causing poor visibility — increase morbidity and even premature mortality.

Airborne acids can be traced to three primary sources: sulphur dioxide (SO_2), nitrogen oxcides (NO, NO_2) and ammonia (NH_3). SO_2 is emitted when fossil fuels are burnt. Its main sources are coal- and oil-burning power plants. Nitrogen oxides originate not only from nitrogen in fuel but also from nitrogen in air. They come largely from the exhausts of cars and trucks and from the flue gases of energy production. Atmospheric ammonia is almost entirely a by-product of animal waste on farms. Sulphur is by far the biggest problem, accounting to roughly 60 per cent of the aggregate acidification in Europe.

Sulphur and nitrogen oxides stay aloft for one to three days and are transported by the winds for distances ranging from 50 to 2000 kilometers. Ultimately, however, they are removed from the atmosphere by rain — wet deposition or acid rain — or by contact with plants and surface water — dry deposition. About 30 per cent of Europe's SO_2 emissions return in precipitation, 50–60 per cent is deposited in dry form as gaseous SO_2 or sulphur ions and the remainder is transported out of Europe.

The use of the atmosphere as a dump for pollutants makes the environmental problem transnational. Emitting countries bear only a fraction of the costs in the form of harmful deposition, because considerable amounts of emissions can be transported by the winds to other nearby countries. A regional externality is thus created, and the conventional prediction is obtained that non-cooperation between the countries on environmental protection results in too high emissions evaluated from their collective viewpoint (see, for example, Mäler 1990).

The incentives for cooperation among the countries concerned are strong, and especially the Nordic countries and Canada have taken initiatives in establishing international treaties limiting the emissions of harmful air pollutants (see, for example, Mäler (1990) or Newbery (1990) for accounts of international cooperation). These countries are large net importers of acid rain because of their unfortunate downwind location relative to their polluting neighbours. Their northern climates make them also more vulnerable than others to acid rain.

Most of the efforts to cut emissions have been aimed at sulphur dioxide. The 21 signatories of the Helsinki protocol of the Convention on Long-Range Transboundary Air Pollution have committed themselves to reducing SO_2 emissions to 30 per cent below the 1980 levels by 1993. About half of these countries have declared more ambitious cuts ranging from 40 to 80 %. But not much has been achieved: according to estimates made at IIASA the European SO_2 emissions will be only 18 per cent lower in the year 2000 than in 1980. The reason is that not all polluting countries are willing to comply with these regulations and some will in fact increase their emissions.

Given the free-rider and other problems associated with efficient full-scale cooperation between the European countries affected by the acid rain, some nations have taken direct steps towards bilateral agreements on environmental protection. In the autumn of 1989 the governments of Finland and the Union of Soviet Socialist Republics signed an action plan for the purpose of limiting and reducing the deposition and harmful effects of air pollutants emanating from areas near their common border (Action Programme 1989). These areas include the whole territory of Finland and the following regions in the Soviet Union: Kola, Karelia, Leningrad and Estonia. The parties agreed that, in addition to active participation in international cooperation, they will reduce the total annual sulphur emissions by 50 per cent in these areas as soon as possible but by the end of 1995 at the latest. The reductions will be calculated on the basis of the 1980 levels. Nitrogen emissions were agreed to be reduced in such a way that after 1994 they will not exceed the 1987 levels. In 1993 the parties will agree on further reductions, the goal being not to exceed the critical loads, i.e. the amounts which do not considerably affect the environment.

This paper sets out to evaluate the net benefits to both parties of this kind of cooperation. Because of data problems, the analysis is confined to sulphur emissions. The next section presents the emission data, a model describing the transportation of sulphur between Finland and the nearby areas of the Soviet Union as well as abatement costs. Section 3 contains an analysis of the optimal form of cooperation and an evaluation of the signed agreement. The current paper extends our previous one (Kaitala, Pohjola and Tahvonen 1990a) by providing a more detailed regional analysis of the problem. Finland is divided into three areas and the nearby Soviet Union into four.

2 The data and the model

In 1988 the Finnish-Soviet Commission for Environmental Protection established a joint programme for estimating the flux of air pollutants emitted close to the border between the countries. It consists of the estimation of emissions, model calculations of transboundary transport of pollutants, analysis of observational results from measurement stations and conclusions for emissions reductions. The emissions inventory includes sulphur, nitrogen and heavy metals.

Table 1 gives information about the depositions and emissions of sulphur in the relevant regions in the years 1980 and 1987. Depositions were calculated by Tuovinen, Kangas and Nordlund (1990) by applying the latest version of the long-range transport model for sulphur developed at the Western Meteorological Centre of the European Monitoring and Evaluation Programme (EMEP). Emission data approved by both the Finnish and Soviet parties have been used as inputs in the model calculations. Finland is here divided into three subregions — Northern, Central and Southern Finland — and the nearby areas of the Soviet Union into four — Kola, Karelia, Leningrad and Estonia (see figure 1). The area of this Soviet territory is about 30 per cent larger than Finland.

Both components of pollution are much higher in the nearby areas of the Soviet Union than in Finland. In 1987 the Soviet emissions were four times higher than the Finnish. However, the trends are declining in both areas. The numbers in the parentheses in Table 1 denote exogenous deposition, that is, deposition originating from emissions in other countries and the rest of the Soviet Union as well as deposition coming from unidentified (both natural and man-made) sources. About half of the total sulphur problem can be covered by the bilateral analysis.

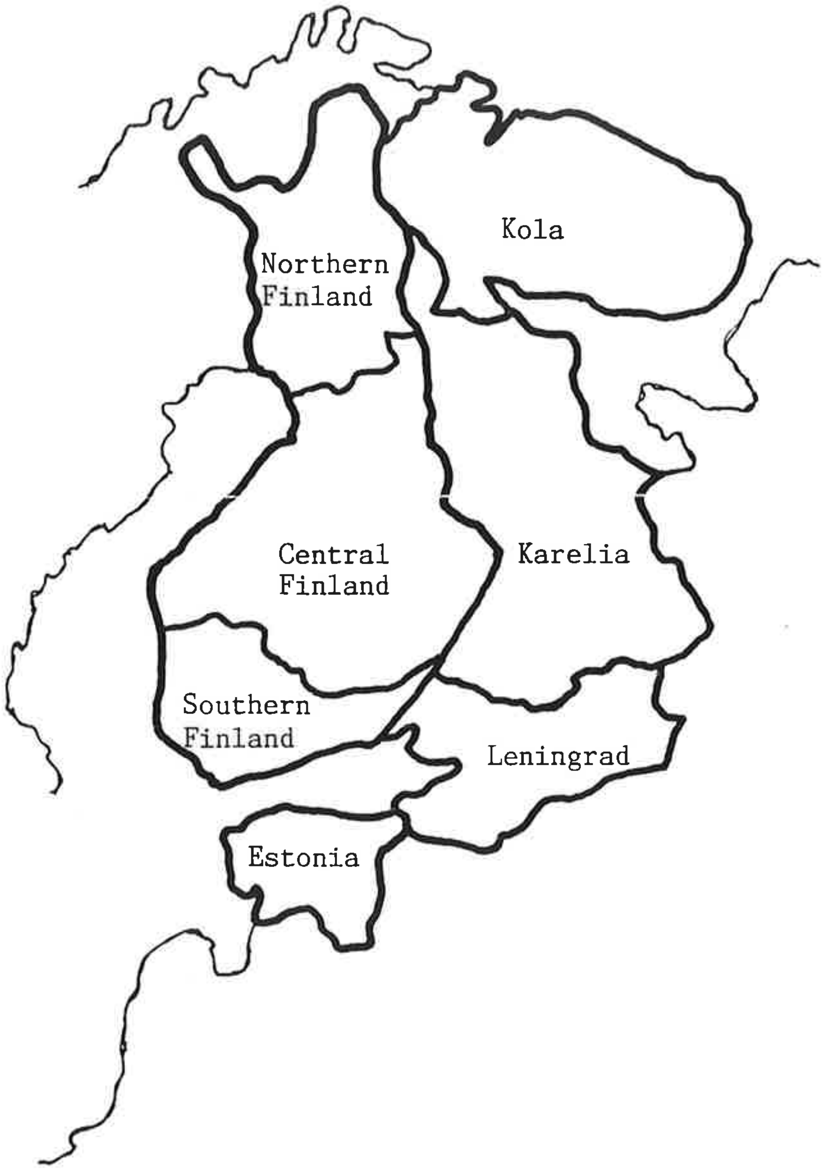

Figure 1: Regional division of Finland and the Soviet Union

Table 1: Sulphur emissions and depositions in 1980 and 1987
(1 000 tons per year)

	Emission E		Deposition Q			
	1980	1987	1980		1987	
Northern Finland	18	5	50	(27)	46	(26)
Central Finland	107	60	124	(66)	98	(59)
Southern Finland	167	97	89	(38)	66	(35)
Finland total	**292**	**162**	**263**	**(131)**	**210**	**(121)**
Kola	362	350	156	(36)	131	(27)
Karelia	85	85	118	(65)	95	(50)
Leningrad	125	112	108	(57)	88	(46)
Estonia	120	104	71	(38)	60	(32)
Nearby USSR total	**692**	**651**	**453**	**(196)**	**374**	**(155)**

Source: Tuovinen, Kangas and Nordlund 1990

Tuovinen, Kangas and Nordlund (1990) have also estimated an annual sulphur budget between the three Finnish and the four Soviet areas for the year 1987. It can be used to formulate a sulphur transportation matrix indicating how the emission in one area is transported in the atmosphere for deposition in another. The columns of table 2 specify the deposition distribution between the regions of one unit of sulphur emitted in each area. The large numbers on the diagonal show how important own sources of pollution are for each region. The column and row sums are not equal to unity because all areas both emit sulphur to and receive it from the rest of the world.

Table 2: Sulphur transportation matrix for the year 1987

	Emitting region:						
	NFin	CFin	SFin	Kol	Kar	Len	Est
Receiving region:							
Northern Finland	.200	.017	.010	.046	.012	.000	.000
Central Finland	.000	.300	.062	.011	.047	.036	.029
Southern Finland	.000	.017	.227	.003	.000	.027	.038
Kola	.000	.017	.000	.286	.023	.009	.000
Karelia	.000	.033	.031	.017	.318	.045	.019
Leningrad	.000	.017	.031	.003	.012	.268	.058
Estonia	.000	.000	.031	.000	.000	.018	.221

Source: Tuovinen, Kangas and Nordlund 1990

The asymmetry of the pollution problem can be seen by combining the information in tables 1 and 2: in 1987 about 19 per cent of sulphur deposited in Finland originated from the nearby Soviet areas whereas only 3.5 per cent of their deposition came from Finland. The reason for this does not lie in the behaviour of the atmosphere (table 2) but is to be found in the asymmetry of the emissions: in 1987 the emissions of the nearby Soviet areas were about four times higher than the Finnish.

A sulphur transportation model can now be constructed on the basis of tables 1 and 2. Let E_i and Q_i denote the annual emission and deposition of sulphur, respectively, in region i, and let A stand for the matrix of table 2 and B for the vector of exogenous deposition in 1987 as specified in the last column of table 1. The model can then be expressed in vector notation as

$$Q = AE + B. \tag{1}$$

For further analysis it is useful to partition the vectors according to the countries: $Q = (Q_F, Q_S), E = (E_F, E_S), B = (B_F, B_S)$, where the subscript F refers to Finland and S to the nearby areas of the Soviet Union. Matrix A can then be written as

$$A = \begin{pmatrix} A_{FF} & A_{FS} \\ A_{SF} & A_{SS} \end{pmatrix}. \tag{2}$$

The dimensions and contents of each submatrix are easily seen from table 2. The (i,j)-component of, say, A_{FF} is denoted by a_{FFij}.

Given the sulphur transportation model, let us next consider the costs of air pollution. Following Mäler (1990), these can be thought of as having two components: the first is the cost of abating sulphur emissions in region i, $C_i(E_i)$, and the second the damage, measured in monetary units, that sulphur deposition causes to the environment, $D_i(Q_i)$. The total costs to Finland can then be written as

$$J_F(E_F, E_S) = \sum_{i=1}^{3}\{C_{Fi}(E_{Fi}) + D_{Fi}(Q_{Fi})\}. \tag{3}$$

and to the nearby areas of the Soviet Union as

$$J_S(E_F, E_S) = \sum_{i=1}^{4}\{C_{Si}(E_{Si}) + D_{Si}(Q_{Si})\}. \tag{4}$$

The regions have here been indexed in the same way as in table 2, i.e., $F1$ denotes Northern Finland, $S1$ Kola and so on.

Both cost components are assumed to be continuous, convex functions of their arguments. It is reasonable to regard $C_i(E_i)$ as decreasing in E_i, and $D_i(Q_i)$ as increasing in Q_i.

The cost function $C_i(E_i)$ is defined as the minimal cost envelope encompassing the entire range of sulphur abatement options for region i in a given time period. The costs can be calculated for various sulphur reduction requirements ranging up to the maximal technologically feasible removal. The HAKOMA project at the Tehnical Research Centre of Finland has produced such regional cost functions by applying an engineering approach in estimating the direct costs of sulphur reductions in both combustion processes in energy production and non-combustion processes in industries using inputs containing sulphur. The annual costs, measured in million Finnish marks, have been estimated on the basis of expected energy demands for the year 2 000, and they include both capital and operating costs. The former have been obtained by assuming that the existing plants are operated for 15 years and and those to be established for 25 years. An 8 per cent annual nominal interest rate has been used in cost calculations.

Two main options to reduce emissions in energy production have been considered in constructing the cost functions. The first one is sulphur abatement through in-furnace lime injection and flue gas desulphurization. The second is switching to the use of low sulphur heavy fuel oils in combustion systems. In calculating costs for non-combustion processes industry-specific costs per abated amount of sulphur have been applied.

Here we use quadratic approximations of the piecewise linear functions produced by the HAKOMA project with the assumption that only the parts decreasing in E_i are relevant for the analysis. Let

$$C_i(E_i) = \alpha_i(\bar{E}_i - E_i) + \beta_i(\bar{E}_i - E_i)^2 + \gamma_i, \tag{5}$$

where $\bar{E}_i$ denotes the actual emissions of region i in the base year, i.e. in 1987. The parameter α_i has been chosen to be equal to the observed marginal costs at $\bar{E}_i$ and γ_i to be equal to the respective total cost. β_i is estimated by the ordinary least squares technique.

Table 3 presents the parameters of (5) for the seven regions. Because the quadratic function approximates rather poorly the sulphur abatement costs in Kola, its cost function is here adjusted by making it consist of two components: first, of a linear segment describing the abatement costs for initial reductions of emissions from the 1987 level down to $E_{S1} = 98$ and, second, of a quadratic segment at $\bar{E}_{S1} = 98$.

Table 3: Abatement cost function parameters
(standard deviations in parentheses)

	α	β	γ
Northern Finland	10.0	2.093	5.9
		(1.181)	
Central Finland	3.8	0.172	33.0
		(0.012)	
Southern Finland	4.6	0.068	53.6
		(0.006)	
Kola			
- for $98 < E_{S1} \leq 350$:	1.0	0.0	0.0
- for $0 < E_{S1} \leq 98$:	1.0	0.077	252.0
		(0.005)	
Karelia	4.0	0.045	0.0
		(0.004)	
Leningrad	6.0	0.051	0.0
		(0.003)	
Estonia	2.0	0.015	0.0
		(0.014)	

It is much harder to obtain information about the damage functions $D_i(Q_i)$. In principle, one could estimate the impacts of sulphur deposition on, say, the growth of forests in each region and then assess the monetary value of the damage caused. Although interesting research is in progress on the effects of changing environmental factors on forest growth, the results are not yet in a form which can easily be subjected to an economic analysis (see, however, Kaitala, Pohjola and Tahvonen (1990b) for initial modelling experiments). Therefore, we here apply an indirect way, suggested by Mäler (1990), of estimating the damages resulting from sulphur deposition. The idea is a simple one: it is assumed that actual sulphur emissions are the results of rational choices by nations acting in isolation and, therefore, reveal to an outside observer the implicit cost resulting from sulphur deposition.

More specifically, suppose that the policy authorities of Finland and the Soviet Union act independently from each other in carrying out their environmental policies. Then, acting rationally, it is optimal for each country to allow sulphur emissions up to the amount at which the marginal abatement cost in each region equals the marginal damage to the whole nation from further deposition in the specific region. Consequently, the emission levels in Finland are chosen in such a way that

$$-C'_{Fi}(E_{Fi}) = \sum_{j=1}^{3} a_{FFji} D'_{Fj}(Q_{Fj}) \tag{6}$$

for $i = 1, 2$ and 3 and in the Soviet Union so that

$$-C'_{Si}(E_{Si}) = \sum_{j=1}^{4} a_{SSji} D'_{Sj}(Q_{Sj}) \tag{7}$$

for $i = 1, 2, 3$ and 4. These emission levels minimize in each country the national cost function ((3) or (4)) subject to the constraints given by the transportation model (1) and the fixed emissions of the neighbouring nation. Acting in isolation each country pays attention to the deposition of sulphur in its own area only. The externalities between regions are internalized within but not between the countries.

The estimation of the damage functions can be completed easily if — again following Mäler (1990) — we make the simplifying assumption that these functions are linear, i.e.

$$D_i(Q_i) = \delta_i Q_i, \tag{8}$$

where δ_i is positive. Knowing the marginal abatement costs (the α's of table 3) and the transportation coefficients (matrix A in table 2), the first-order conditions (6) and (7) then immediately provide estimates for the δ_i's if the observed emission vector $(\bar{E}_F, \bar{E}_S)$ in 1987 is assumed to be the Nash equilibrium of this acid rain game:

$$\delta_F = (A_{FF})^{-1} \alpha_F, \tag{9}$$

$$\delta_S = (A_{SS})^{-1} \alpha_S. \tag{10}$$

The numerical values of these marginal damage vectors are given in table 4 which for comparison also displays the marginal abatement costs.

Table 4: Marginal abatement (MC) and damage (MD) costs (FIM/kilogram of sulphur)

	MC α	MD δ
Northern Finland	10.0	50.0
Central Finland	3.8	8.9
Southern Finland	4.6	15.6
Kola	1.0	2.6
Karelia	4.0	11.6
Leningrad	6.0	20.2
Estonia	2.0	2.8

Sulphur abatement costs are the lowest in Kola and Estonia — 1 and 2 Finnish marks per kilogram of sulphur, respectively — and the highest in Finnish Lappland — 10 marks per kilo. These estimates reflect the fact that not much has been invested in sulphur abatement in these Soviet regions whereas the acidification of Lappland has been an environmental concern in Finland for a long time. As is seen from table 1, the Finnish sulphur emissions were reduced by 45 per cent from the 1980 level by 1987. The greatest relative reduction was achieved in Northern Finland. Emissions in the nearby Soviet regions were cut by only 6 per cent in the same period.

These facts come out in the estimates of the marginal damage cost. It is the highest in Northern Finland — 50 marks per kilogram of sulphur deposited — and the lowest in Kola and Estonia — about 3 marks per kilo. This approach also reveals that the Soviet decision-makers regard additional sulphur deposition to be about eight times more harmful in the Leningrad area than in Kola or Estonia.

Armed with the damage costs we can now turn to consider the potential benefits of environmental cooperation between the countries as well as to assess its optimal form.

3 The optimal form and benefits of cooperation

A Pareto-optimal sulphur abatement contract between the countries can be derived by minimizing the joint costs

$$J(E_F, E_S) = J_F(E_F, E_S) + J_S(E_F, E_S) \tag{11}$$

with respect to both emissions in the Finnish areas (vector E_F) and in the Soviet regions (vector E_S) under the constraints set by the transportation model (1). The optimal emission vector (E_F^*, E_S^*) is obtained by solving the first-order conditions

$$-C'_{Fi}(E_{Fi}) = \sum_{j=1}^{3} a_{FFji}\delta_{Fj} + \sum_{j=1}^{4} a_{SFji}\delta_{Sj}, \ i = 1,2,3, \tag{12}$$

$$-C'_{Si}(E_{Si}) = \sum_{j=1}^{4} a_{SSji}\delta_{Sj} + \sum_{j=1}^{3} a_{FSji}\delta_{Fj}, \ i = 1,2,3,4. \tag{13}$$

The reciprocal externalities arising from the use of the atmosphere as a dump for air pollutants are internalized if both parties commit themselves to this contract. This follows from the fact that also the damages done to the areas of the neighbouring country are now taken into account in balancing the costs and benefits of sulphur abatement in each country. An obvious precondition for commitment is that cooperation is beneficial to both parties, i.e. that it results in total (abatement plus damage) costs which are in neither country greater but in at least one country strictly less than without cooperation.

Table 5 displays the optimal emissions, the resulting depositions in all areas as well as the monetary benefits from cooperation to both countries. The exogenous deposition (vector B) is assumed to remain at the 1987 level. It does not affect the optimal emission levels but has an impact on the depositions and the total costs. The monetary benefit has been calculated for each country by subtracting the optimal cost from the non-cooperative cost: benefit to country I equals $J_I(\bar{E}_F, \bar{E}_S) - J_I(E_F^*, E_S^*)$, $I = F, S$.

Table 5: The consequences of cooperation and its annual monetary benefits

	Emissions (10^3 tons) E^*	Emission reduction (%)	Depositions (10^3 tons) Q^*	Deposition reduction (%)	Benefit (10^6 FIM) $\bar{J} - J^*$
Northern Finland	5	0.0	34	26.1	
Central Finland	58	3.3	92	6.1	
Southern Finland	89	8.2	62	6.1	
Finland	**152**	**6.2**	**188**	**10.5**	**667**
Kola	82	76.6	54	58.8	
Karelia	74	12.9	86	9.5	
Leningrad	105	6.3	83	5.7	
Estonia	74	28.8	53	11.7	
Nearby USSR	**335**	**48.5**	**276**	**26.2**	**- 31**

The joint cost minimization requires the Soviet Union to cut the aggregate sulphur emissions by almost 50 per cent from the 1987 level in the areas near the Finnish border. The greatest reductions should be carried out in Kola and Estonia. The abatement activities should be concentrated on these regions for two reasons: first, their sulphur abatement costs are rather low and, second, their emissions contribute significant amounts to deposition in Northern and Southern Finland where the marginal damage of pollution is rather high. The Finnish emissions were quite close to the optimal level in 1987 — they should have been 8 per cent lower in the southern area and 3 per cent smaller in the central part of the country.

This asymmetry in the abatement requirements between the countries can be explained by the asymmetries in marginal abatement costs (table 3) and observed emissions levels (table 1). Cutting emissions by one unit is roughly four times more expensive in Finland than in the Soviet areas. Finland receives about 19 per cent of her sulphur deposition from the four Soviet areas whereas its contribution to their deposition is only 3.5 per cent.

Table 5 also reveals that Finland benefits from the cooperation by 667 million marks a year. The abatement costs increase by some 50 million but the damage cost decrease by 717 million when compared to the case of non-cooperation, i.e. the situation which prevailed in 1987. The greatest gain accrues to Northern Finland. The Soviet Union, however, loses. The proposed substantial cuts in emissions cost 455 million Finnish marks but the damage costs are only 424 million smaller than without any cooperation. The loss is 31 millions a year.

As no sovereign state can be forced into cooperation, it is reasonable to expect that in order to sign such an agreement the Soviet Union should be compensated for at least the loss. This means that Finland should pay the Soviet Union 31 million marks a year for 15–25 years which is the investment period behind the abatement cost calculations. The compensation should be even greater if sharing the net benefit from cooperation is regarded to be fair. Assuming that the net gain is split equally between the countries, the compensation raises to 349 millions a year.

It may here be of some interest to examine the consequences of the actual agremeent signed in 1989 between the countries and to compare it with the year 1987. This is done in table 6. The parties have agreed on the reduction of sulphur emissions by at least 50 per cent from the 1980 levels. The contract, however, does not specify how the aggregate reductions should be allocated between the regions. We have here assumed that emissions are cut by 50 per cent in all areas. The emissions of Northern Finland were in 1987 already smaller than this amount. Therefore, the observed 1987 level has been chosen for it and the upper limits on the emissions of other Finnish areas have been adjusted accordingly.

Table 6: An evaluation of the Finnish-Soviet agreement

	Emissions (10^3 tons) E^*	Emission reduction (%)	Depositions (10^3 tons) Q^*	Deposition reduction (%)	Benefit (10^6 FIM) $\bar{J} - J^*$
Northern Finland	5	0.0	38	17.4	
Central Finland	55.5	7.5	89	9.2	
Southern Finland	85.5	11.6	60	9.1	
Finland	**146**	**9.9**	**187**	**11.0**	**492**
Kola	181	48.3	81	38.2	
Karelia	42.5	50.0	75	21.1	
Leningrad	62.5	44.2	71	19.3	
Estonia	60	42.3	49	18.3	
Nearby USSR	**346**	**46.9**	**276**	**26.2**	**- 217**

It is rather surprising that the agreement, as interpreted here, results in the same total depositions in both countries as the optimal contract. The emissions, however, are not equal: in Finland they are smaller and in the Soviet areas larger than what is optimal according to the Pareto solution. The Soviet loss is also greater, and the total net benefit is much smaller than the optimum. These results follow from the suboptimality of the 50 per cent rule, but they also depend on the way we have allocated the cuts between the regions.

4 Conclusions

This paper has demonstrated a case for the 'victim pays principle' in the environmental cooperation between Finland and the Soviet Union. The 'victim' is Finland because it is the net importer of sulphur in the bilateral transportation of air pollutants between the countries. It should give monetary compensation to the Soviet Union to induce it to cut emissions by the amounts implied by the minimization of the joint costs from pollution. This is economically rational for Finland because abating sulphur is much less expensive in the nearby areas of the Soviet Union than in the own country.

Pareto-optimal environmental cooperation implies quite drastic cuts in the Soviet emissions. They should be reduced by about 75 per cent in Kola and 30 per cent in Estonia. To meet these requirements it would be sufficient to renew the technologies used in the two nickel smelteries situated in the Kola peninsula and in at least one of the Estonian power stations burning oil shale. Much smaller cuts — 13 and 6 per cent respectively — are required in Karelia and Leningrad.

The agreement signed between the parties in 1989 turned out to be inefficient in minimizing the joint pollution costs. The reason is the requirement of a uniform 50 % reduction from the 1980 levels. However, the marginal abatement costs as well as marginal damages from acid rain vary greatly across regions, making equiproportional emissions reductions inefficient.

The signed agreement was shown not to be beneficial to the Soviet Union. As there is no reason to believe that the environment can be given greater attention in the current Soviet policy-making than in 1987, one may expect that terms of the contract will not be fulfilled without monetary support from Finland. In fact the Finnish authorities are now devising a scheme aimed at reducing emissions in Kola by about 90 per cent. It involves both technical and economic assistance from Finland. Such a cut would be substantial enough to reduce the Soviet emissions below the level specified in the agreement. But it is not optimal according to the results of our study. Emissions should be reduced in other areas as well, especially in Estonia.

Our analysis was based on a restrictive set of assumptions, and needs to be qualified in a number of respects. In particular, alternative ways of estimating the damage costs should be investigated as is done, for example, in Newbery (1990). An analysis is terms of critical loads or target pollution levels might also provide a workable alternative which can be used to test the sensitivity of the conclusions obtained from the revealed-preference approach. Finally, the long-run impacts of acidification should be given more attention because sulphur is a stock pollutant as well as a flow pollutant (see Kaitala, Pohjola and Tahvonen (1990b) for some initial experiments).

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