WORKING PAPER

International Environment Threats through Transboundary Acidification: Nation-Level Positions within the International Environmental Structure

Detlef Sprinz

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IIASA
International Institute for Applied Systems Analysis

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Preface

Detlef Sprinz was a member of the Transboundary Air Pollution Project as part of the 1989 Young Scientists Summer Program at IIASA. In this paper, he uses the Regional Acidification Information and Simulation (RAINS) model in a rather unique way: to show which European nations are in advantageous or disadvantageous positions with respect to acidic deposition, and how this could affect their perspective for international negotiations.

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Abstract

Cross-national environmental pollution can be understood as a limitation to national welfare caused by actors beyond the jurisdiction of a state. Both, the international environmental structure as well as domestic variables may account for the variation found across states with respect to international environmental regulation. The author wishes to explain why the European member states of the United Nations Economic Commission for Europe (UNECE) subscribe to or refrain from the international regulation of the Long Range Transport of Air Pollutants (LRTAP), which is commonly called "acid rain."

This study focuses on the question: Is there an international environmental structure (like international emission/deposition patterns) for *sulfuric* acidification in Europe which might influence the extent of international environmental regulation? Three perspectives on the international environmental structure are presented: 1. The deposition perspective: Each country is treated as a unit which *receives* pollutants from other countries. 2. The international trade perspective: Each country is analyzed as a participant in unwanted international *"trade"* of environmental pollutants. 3. The emission perspective: Each country is viewed as a unit which *threatens other nations via exported emissions.* The author used the results generated by the Regional Acidification and INformation Simulation model (RAINS) of the International Institute for Applied Systems Analysis (IIASA) to test hypotheses related to each of these perspectives.

The analyses demonstrate that Central Europe is in a disadvantageous position from a deposition perspective. Furthermore, some East European countries are strongly externalizing their environmental problems because they are net exporters of pollutants; from an emission perspective it can be show that some East European countries are likely to be exposed to diplomatic pressure since their exported emissions pose substantial threats abroad. In conclusion, states find themselves in grossly unequal positions with respect to internationally caused *sulfuric* acidification. The paper concludes with a theoretical interpretation of the findings and points to options for future research.

Acknowledgements

This study is part of a political science dissertation at the University of Michigan, Ann Arbor (USA). The goal of the dissertation is to show how both the (i) international environmental structure and how (ii) domestic factors influence governmental positions in international environmental negotiations on the regulation of the environment. The framework outlined in the dissertation facilitates the comparative analysis of international environmental problems, and it will be applied to the "acid rain" problem in Europe.

The author is grateful for the opportunity to participate in the 1989 Young Scientists' Summer Program of the International Institute for Applied Systems Analysis (IIASA). The members of the Transboundary Air Pollution Project (TAP) provided invaluable support for the use of the Regional Acidification and INformation and Simulation model (RAINS). The author thanks Dr. Roderick Shaw and Dr. Robert Pry for very stimulating discussions. The normal caveats apply. Funding was generously granted by the West German Association for the Advancement of IIASA, Jülich, and by the director of IIASA, Dr. Robert Pry.

Introduction

A brief overview of the theoretical rational of the article will be presented in the first section which is followed by a review of the simulation model used for data generation. In section 3, which forms the core of the paper, indicators for the study of the international environmental problem under investigation are presented in conjunction with the empirical findings. Section 4 looks at the theoretical implications of our findings, points to the shortcomings of this research, and outlines future paths for theory development.

1. The International Structure and Preferences for International Environmental Regulation

Global environmental problems redistribute national welfare by imposing net costs on some states while other states receive net benefits. As has been argued with the "billiard ball" model with respect to the balance of power (Morgenthau/Thompson 1985), states respond to "problem pressure" caused by foreign actors. Status quo policies of states with regard to pollution may be considered to serve as the reference case. A state's policies are geared towards improving its position relative to the status quo; i.e., states want to reduce their long-term "vulnerability" (Keohane/Nye 1977) and use domestic policies, or they redesign their foreign environmental policy for this purpose (Prittwitz 1984). In conclusion, states can be conceptualized as unitary, utility-maximizing actors (Bueno De Mesquita 1981) which react to external stimuli.

Although all states are formally sovereign and equal, international air exchange leaves some states in a disproportionately disadvantageous position, while other states experience substantial net benefits. The author would like to demonstrate the degree of inequality among states created by the international environmental structure (Waltz 1979, Organski/Kugler 1980).

The analysis to follow is part of a research design which specifies the dual determinants of national participation in, or abstention from, international environmental regulation (see Figure 1). For some countries, the international structure creates potential net benefits to be gained from international environmental regulation and vice versa. Therefore, the international structure will influence national positions in international negotiations on the environment. In addition, a disadvantageous position within the international environmental structure is likely to lead to more stringent domestic regulation. This hypothesis is likely to hold, since domestic policies may be entertained to ameliorate part of the international environmental problem. Both, perceived benefits from international regulation and the extent of domestic regulation are positively linked to an increased likelihood that nations will participate in international environmental agreements.

This study shows that the geographical location of a country (like an "upwind" or a "downwind" position) is an oversimplified summary of a state's position within the international environmental structure. Indeed, the Regional Acidification and INformation and Simulation model (RAINS) developed by the Transboundary Air Pollution Project at the International Institute for Applied Systems Analysis (Laxenburg/Austria) facilitates a rigorous analysis of interdependence with respect to the inter-country exchange of pollutants.[1]

2. The Regional Acidification and Information and Simulation Model (RAINS)

Since its creation by the (military) superpowers in the early 1970s, the International Institute for Applied Systems Analysis (IIASA) has developed tools for the solution of problems in a diverse set of fields. The common goal has been to form scientific tools for application in different political systems and thereby to aid policy makers in increasing the set of feasible solutions for problems like transboundary acidification. The Transboundary Air Pollution Project (TAP, formerly the Acid Rain Project) has developed the simulation model RAINS since 1984, and it is semi-officially accepted by the United Nations Economic Commission for Europe (UNECE) for scientific consulting purposes related to the 1979 Convention on the Long-Range Transport of Air Pollutants (LRTAP) (UNECE 1989, 1988). The implicit goal for RAINS was to separate (1) the problem of information generation from (2) the problem of arriving at politically acceptable solutions for the member states of the UNECE.

The model consists of modules which capture the emission, the transport, and the deposition of sulphur and nitrogen oxides.[2] In addition, impact modules for (1) forest soil acidification in Europe, (2) lake acidification in Norway, Sweden, and Finland, and for (3) direct forest impacts in Europe have been developed. A cost module for the study of abatement schemes is available for sulphur oxides and allows to design cost-minimizing clean-up strategies in conjunction with an optimization algorithm. Besides working as a synthesizer of many natural science disciplines and environmental economics, the model stands out for allowing to simulate scenarios ("front end" changes by the user) as well as to run in an optimization mode. The cost optimization modules allows international

[1] The analysis of the atmospheric transport of nitrogen is also included in RAINS. The author will undertake a complementing analysis once the relevant databases are updated and tested.

[2] The best summary to date is the article by Alcamo et al (1988) and the forthcoming book by Alcamo et al.

deposition reduction goals to be achieved at minimum total cost to the UNECE countries. Alternatively, given amounts of money can be optimized with respect to their impact on deposition.[3]

The RAINS model will include an optimization module for the simultaneous reduction of sulphur and nitrogen oxides in the near future. In conclusion, RAINS is currently the best software for the study of acidification in Europe, and its output is useful for the political analysis of an important environmental problem.

3. Indicators of the Position of States Within the International Environmental Structure

With respect to international air pollution exchange, I suggest three major perspectives. Firstly, each nation can be looked at as a receptor of acid deposition, the origin of which are domestic and foreign ("deposition perspective"). Second, one may look at nations as (involuntarily) "trading" air pollutants: Some nations are net importers of pollution while other nations have the benefit of being in a net exporter position ("international trade perspective"). Third, nations are able to look at their own emissions as potential threats to domestic or foreign ecosystems ("emission perspective"). Each perspective will be developed in more detail below. Throughout the analysis we only take those sulphur pollutants into account which can be attributed to *political* actors, i.e., we omit

(i) "background contributions", which cannot be empirically attributed to *any* political entity, as well as

(ii) emissions which are not deposited in the member states of the Cooperative Programme for the Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP), which is the UN-supported monitoring program for acidification in Europe.

3.1 Description of the Scenarios Considered

For theoretical reasons I assume that states wish to maximize utility. Then, a government is expected to undertake only those policies from which it expects to gain positive returns, since scarce resources are allocated in the political process. In the case of the international transport of acidic pollutants (reviewed in Alcamo et al forthcoming, ch.2), we would expect governments to pursue the following goals:

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[3] The optimization module focuses on international cost efficiency. This does not mean, that the sets of solutions are acceptable to policy makers.

(i) to minimize stress to domestic ecosystems,

(ii) to offset international interdependence, as evidenced by foreign caused depositions in one's own country, by depositing domestic emissions abroad (i.e., externalizing an environmental problem), and

(iii) to avoid to be diplomatically targeted by other states because of one's impact on foreign ecosystems.

Therefore, we should expect countries

(i) to minimize depositions in its country,

(ii) to prefer the position of a "net exporter" of air pollutants over the position of a "net importer" of pollutants, and

(iii) to minimize its exported emissions (see below).

The goals outlined above may be partially contradictory.

It cannot be assumed that energy policies which show unexpected impacts today - but were planned some 30 years ago - *willfully* determine a states position with respect to the international environmental structure as outlined below. More likely, states find themselves in different positions with respect to the relatively new issue of international environmental politics because of the incomplete foresight of previous generations of policy-makers.

In the analyses to follow, four basic "scenarios" have been investigated with the help of RAINS. The actual situation in 1980, the Official Energy Path 1980 ("OEP 1980"), was chosen as the "real world" referent case. For this year, the relevant emission data and the meteorological model have been developed and verified.[4] Three simulated future scenarios were developed:

(i) the Official Energy Path 2000 (OEP 2000), a compilation of national energy paths by the International Energy Agency (1986) and the UNECE (1987); in comparison to OEP 1980, it implies no (additional) controls on emissions;

(ii) the Current Reductions Plan 2000 (CRP 2000), which is a set of policies announced by governments in response to the implementation of the 1985 Sulphur Protocol to the 1979 UNECE Convention on the Long-Range Transport of Air Pollutants (UNECE 1985; compiled by the TAP staff, Amann 1985, 5);[5] and

[4] The meteorological model is based on the combined yearly averages of 1979, 1980, 1983, and 1984. This model was developed by EMEP; the emitter-receptor coefficients are assumed to be constant over time.

[5] Some governments announced that they will reduce sulphur emissions in excess of the requirements of the protocol. Other governments, like Greece, did not sign the protocol and anticipate increases in emissions. Both types of information are included in CRP 2000.

(iii) the Maximum Feasible Reductions 2000 scenario (MFR 2000). This scenario assumes that all states pursue all emission reductions which are "technically feasible" with the best available technology (Shaw et al 1988, 10; in this context it was assumed that West German technology is perfectly tradable internationally).

In conclusion, three scenarios for the year 2000 represent a continuum which ranges from no specific policies to combat international acidification (OEP 2000), policies to be implemented in some countries in order to reduce environmental degradation (CRP 2000), and an all-out effort with technological means (MFR 2000). The raw matrices used in the analysis (Tables 1 through 4) are crosstabulations of the emitting countries (columns) with the depositing countries (rows).

The raw matrices, generated by RAINS, report only integers. Although this is of no importance for major and medium-sized polluters, the results for Luxembourg and Albania seem to be susceptible to rounding error.[6] Therefore, these two countries were removed from the analysis. The Soviet Union and Turkey, as the most westbound countries of the EMEP region,[7] have only part of their surface area incorporated in the meteorological model. Because relatively fewer monitoring stations are available here, our indicators, which are derived from the EMEP meteorological transport matrix, may be less precise in comparison to other countries. Indicators which take the surface area into account had been appropriately adjusted for the Soviet Union and Turkey. The same holds true for the population-based indicators involving the Soviet Union; however, the same has not been done yet for Turkey.[8] The emission data reported are not identical with official data provided by the UNECE (compare (i) Tables 1 and 3 with (ii) Table 5). The Transboundary Air Pollution project at IIASA adjusts official data, since these data are likely to be misleading in some cases due to "underreporting." We suspect that there is another "rounding-off" problem in the MFR 2000 scenario since the amounts of sulphur involved have been sharply reduced. However, for large countries this should have a smaller impact than is the case for small countries.

[6] For illustration purposes, the reader may compare the error of (i) "99.4" being reported as "99" with (ii) "0.4" being reported as "0".

[7] The author uses the geographers' definition of Europe.

[8] I am indebted to Ger Klaasen, formerly with the Institute for Environmental Studies, Free University of Amsterdam and now with the Transboundary Air Pollution Project, IIASA, for sharing the surface and population data for 1980 with me; Sergey Vasin, Department of Demography, Moscow, kindly helped me to adjust the population data of the SU.

3.2 The Deposition Perspective

Taking the deposition perspective, we are interested to know the origin of an environmental threat. Before turning to more complicated analyses, we should have a look at the deposition which can be attributed to states. Table 6 gives the relevant deposition flux of sulphur in $g/m^2/year$ which was computed from the raw deposition figures and the surface area of the country monitored by EMEP. The GDR, the CSSR, Poland, Belgium, and Hungary[9] do stand out for their relative "leadership" in deposition flux. Other factors held constant, these countries are the worst affected by acidification, whereas - according to this indicator - the Scandinavian states, Portugal, and Ireland enjoy some ecological advantage.[10] In addition, we can observe that the MFR 2000 scenario does introduce a substantive decline in depositions and thereby contributes to a higher degree of "environmental security." The change in the average deposition[11] for the GDR from 7.92 $g/m^2/year$ (OEP 1980) to 1.41 $g/m^2/year$ (MFR 2000) especially stands out. Some countries can reduce their depositions drastically if MFR 2000 is implemented, while other countries do not have the same opportunity. Therefore, it is important to avoid "envy" in international negotiations on the environment: Even if all countries introduce the same stringent pollution controls (e.g., MFR 2000), it may not be possible for *each* state to achieve the *same* low level of deposition flux and therefore the same degree of environmental security.

We may also shed light on the question, to what degree the deposition problem is "homemade", i.e., what the contributions of domestic emissions of sulphur are, and to what degree the problem is caused by foreign actors. Our analysis shows (Figure 2), that countries are often, although not always, their worst "enemy"; i.e., in most countries, domestic emissions are the predominant contributor to deposition. On a country-by-country average, more than 40% of the deposition is caused domestically. This result holds across the four scenarios.

More precisely, we can distinguish two groups with respect to domestically caused deposition.[12] First, in the U.K. and Spain more than 80% of depositions is domestically caused. Second, in contrast, Austria, the Netherlands, Norway, and Switzerland are the exception from the rule that states are their foremost "enemy" (not detectable from Figure

9 Country codes in the tables and figures are taken from RAINS and reflect the international country codes of the automobile sign convention.

10 Note: This analysis does not take ecosystem sensitivity into account.

11 For simplicity, we assume that all depositions are distributed equally across the whole country. Using averages just serves as a first approximation of the magnitude of the environmental problem.

12 Since most inductive statistical methods require a sample size larger than 25, we use a simple procedure: Throughout this article, we focus on those groups which are about one standard deviation above the mean and juxtapose these states with a group of countries which is about one standard deviation below the mean.

2). With one exception, each of these countries contributes 20% or less to the deposition flux in their own countries.

In order to ensure their environmental security, many countries do depend on collaboration with other states. However, the degree of international collaboration needed to achieve environmental goals varies form country to country. We can conclude that, on the one hand, some states basically have a *domestic* problem; on the other hand, some countries receive very substantial contribution to depositions from *foreign* sources. In order to arrive at a combined concentration measure of *imported and of foreign* contributions, we developed the Deposition Indicator for Sulphur 1 (DepIS1)

$$(1) \qquad DepIS1_i = \sqrt{\sum_{i=1}^{N} (\%w_{ij}\ deposition^2)} \qquad \{i=1,\ldots,j,\ldots,N\}$$

where $\%w_{ij}^2$ is the squared percentages of country j's contribution to deposition in country i. The squaring of the percentage contribution to deposition is a weighting procedure ("focus"), which emphasizes the importance of large contributors and gives low weight to small contributors. The justification for this procedure is that states give disproportionate attention to those states which cause a major problem in country i and vice versa. We took the square root of the raw indicator to magnify the effect. Actually, DepIS1 and the concentration indicators to follow are simplified measures of skewness.

The indicator DepIS1 may reach a maximum of 1.0 if country j contributes 100% of the deposition in country i;[13] the lower bound is reached if all countries contribute equal shares, i.e., it equals $\sqrt{1/N}$, where N is the number of countries contributing to deposition. In our case N equals 25, so the lower bound[14] is 0.20.

This measure of focus is relatively stable for geographically large countries (data not presented here). Two polar groups can be distinguished by DepIS1. First, the U.K., Spain, and Turkey rely on a very small group of contributors. Second, Norway, Sweden, Denmark, and Austria rely on a relatively large number of contributing countries. These properties hold across scenarios. However, the domestic contribution to deposition is included in DepIS1.

Students of international politics often try to measure the extent to which a country has influence over another country. Therefore, we wish to concentrate on *imported depositions*. The Deposition Indicator for Sulphur 2 (DepIS2) is a derivative of DepIS1 and excludes domestic contributions to deposition.

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[13] Recall: i may equal j.

[14] Theoretically, the lower bound of DepIS1 is zero, i.e., a country has no depositions at all. However, this is a very unlikely case in reality.

(2) $$\text{DepIS2}_i=\sqrt{\sum_{i=1}^{N}(\%w_{ij}\ \text{deposition}^2)} \qquad \{i=1,...,j,..,N;\ i\neq j\}$$

The constancy of the mean score of the indicator across scenarios (data not shown here) came as a surprise since CRP 2000 assumes that some states undertake abatement efforts while other countries do not commit themselves to remedial action (see summary of total emissions in Table 8). On the one hand, Portugal, Ireland, Finland, Switzerland, and Poland have to bargain only with relatively few foreign countries if they wish to reduce depositions in their own country. In the extreme, only one or two foreign countries are needed for substantial reductions; most likely, they are bordering states. On the other hand, the U.K., Sweden, Norway, Austria, Yugoslavia, and France would have to rely on a disproportionately large number of states if they wish to reduce depositions caused by foreign countries. The results are mildly constant across scenarios.

In international environmental relations, countries may threaten each other. Up to now, some indicators of the concentration of transboundary threats have been developed. Olson (1971) argues, that it is easier to find solutions for public good problems, e.g., the reduction of transboundary emissions, if there are only few key members rather than a large group involved. This is supposed to hold, because in small groups the incentive to "free-ride" is reduced since each non-cooperative actor may cause the non-provision of the public good. Therefore, we hypothesize that the more focused the international problem is for each country, the more likely we will find a solution for each country's international environmental problem. In measurement terms we are looking for higher scores on DepIS2 rather than smaller scores. In order to capture the idea of free-riding and the magnitude of the environmental problem simultaneously, we use DepIS2 in conjunction with imported depositions per unit of surface area.[15]

Following Olson, we argue that the internationalized environmental problem with respect to acidification is most difficult to solve for each country if it is dependent on a relatively large number of foreign contributors ($j\neq i$) and if the combined amounts of imports are very substantial. The Threat of Deposition Indicator (ThreatDepIS) reflects this idea.

(3) $$\text{ThreatDepIS}_i=(1-\text{DepIS2})_i \times (\text{Imported Depositions}_i/\text{Area}_i)$$

The amount of dispersion, or the difficulty in forming a coalition to achieve the public good, is expressed by the term (1-DepIS2). This expression has an upper bound of $1-\sqrt{(1/N)}$ and a lower bound of zero. The amount of imported depositions per unit of surface area

[15] The control for area seems justified since, as an approximation, the magnitude of a foreign threat posed by a constant amount of sulphur imports varies negatively with the surface area of the depositing countries.

reflects the magnitude of the international environmental problem for each country. In order to achieve environmental security, countries scoring high on ThreatDepIS will have to "convince" a relatively large number of states to reduce emissions. To be successful, it must be able to commit relatively large amounts of resources to potentially compensate these countries.[16]

It is striking to see that only the MFR 2000 scenario (Figure 3) is able to drastically reduce the mean threat generated by foreign contributions to deposition. It is obvious that states can improve their absolute position, however, it seems unlikely, that a state can escape its relatively disadvantageous position within the international structure. For example, Austria, Belgium, the CSSR, the FRG, the GDR, and The Netherlands remain vulnerable relative to other states. This finding holds across scenarios. A group consisting of Finland, Ireland, Portugal, Spain, the U.K., and the SU shows low scores on this indicator. In general, none of those states with high scores on (1-DepIS2) scores high on ThreatDepIS. This points to the preliminary conclusion that the amount of imported deposition per unit of surface area is more decisive than the measure of dispersion of imported depositions.

Many states in Central Europe bear the burden of having to overcome a relatively substantial foreign threat to their ecosystems. This group transcends categories of geographical size as well as type of economic system (as of late 1989). From a "problem pressure" perspective we expect that states scoring high on ThreatDepIS would be more likely to pursue agreements than states scoring low on this indicator.

In conclusion, Central European countries are strongly and adversely affected by the international nature of the long-range transport of air pollutants. Rather than supporting a null hypothesis that states find themselves in the same structural position with respect to the deposition of sulphur oxides, evidence points into the opposite direction. If we are interested in measuring the hurdles which states have to overcome in order to reduce *foreign* deposition threats, an indicator of the dispersion of imported emission may be combined with the amount of sulphur imports. High scores on this indicator should point at states which are likely to have difficulties in limiting their outside vulnerability. These states should be more prone to favor multilateral negotiations over bilateral or small group arrangements, however, international vulnerability does not preclude the option of reducing domestic emissions. It has to be noted that our current investigation does not yet take the actual sensitivity of ecosystems to the deposition of sulphur into account.

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16 We assume that status quo policies have achieved some legitimacy internationally. As a consequence, nations dissatisfied with involuntary imports of pollutants have (i) to offer compensation to other countries or (ii) to entertain alternative foreign policy tools to achieve environmental goals.

3.3 The International "Trade" Perspective

In the international trade of commodities, trade balances (for the trade of goods and services) serve as a first approximation of a country's international performance. Analogously, countries import *foreign* emissions and *export* domestic emissions. Thus, a balanced international sulphur "account" would reveal that country i's imported depositions have been matched by an equal amount of (its) exported emissions.[17] Net importers of sulphur do "internalize" an international problem, i.e., they reduce the *international* problem for the remaining countries more than they contribute to it, whereas net exporters do "externalize" part of their emissions. One could also say that the existence of international net exporters of sulphur emissions is at the heart of the creation of an international environmental problem: Some states take a "free ride", whereas the complementary set of states is in a less desirable position.

In the two country case it holds that one country's export surplus is the other country's export deficit. For the case of N countries it can be shown that the sum of all trade deficits and trade surpluses equals zero! Applying the same logic to the international transport of sulphur, only those amounts of sulphur are taken into account which (i) are emitted by EMEP member countries and which (ii) are deposited in these countries. Therefore, the sum of internationally traded sulphur surpluses in the EMEP area is zero.

Table 7 shows[18] us that 17 out of 25 countries remain in a position of either a net exporter or a net importer across scenarios. Some countries may flip from a net exporter position to a net importer position, but in such case, they do not belong to the major actors in the either group.

First, we have a look at the group of net importers, and second, we concentrate on the group of net exporters of sulphur. Two indicators have been developed for the net "importing" countries. Firstly, the Import of Deposition Indicator for Sulphur 1 (ImDepIS1), is computed as the amount of net imports of sulphur from all foreign countries divided by the deposition of sulphur in country i. The second indicator, ImDepIS2, relates the net imports of sulphur to the surface area covered by country i.

(4) $ImDepIS1_i = Net\ Imports_{ij} / Depositions_i \quad \{i=1,...,j,..,N;\ i \neq j\},$

(5) $ImDepIS2_i = Net\ Imports_{ij} / Area_i, \quad \{i=1,...,j,..,N;\ i \neq j\}.$

The first indicator (Figure 4) points at a group of states which internalizes the international problem of acidification, i.e., they partially "absorb" the international

[17] This does not preclude that a country has a deposition problem.

[18] A negative entry points at a net exporter position. The negative mean value for the net sulphur imports of OEP 1980 is caused by the exclusion of Luxembourg and Albania (see above).

environmental problem. This group consists of Norway, Switzerland, Sweden, and Austria in the first three scenarios. The second indicator (Figure 5) illustrates that the CRP 2000 scenario does not necessarily lead to an improvement for all countries over OEP 2000. This is because some states pursue reduction plans in comparison to the OEP 2000 scenario while other states cling to the OEP 2000 scenario for the time being. Thereby, some countries reduce their own exports (via emission reductions), like Austria, while increasing the amount of net imports of sulphur. However, across scenarios the group comprising of Austria, Sweden, Switzerland and the Netherlands shows its vulnerability to net imports per unit of area.

For the "export" perspective, two similar indicators were developed. The Export of Emission Indictor for Sulphur 1 (ExEmIS1) divides the net exports of sulphur of country i to all other countries j by i's level of national emissions; ExEmIS2 is defined as the amount of net exported emissions per 1,000 inhabitants.

(6) $ExEmIS1i = Net\ Exports_{ij}/Emissions_i$ $\{i=1,...,j,..,N;\ i \neq j\}$

(7) $ExEmIS2_i = Net\ Exports_{ij}/Population_i$ $\{i=1,...,j,..,N;\ i \neq j\}$

The analysis of ExEmIS1 (see Figure 6) clearly shows that the GDR is capable of externalizing her acidification problem to a substantive degree in all three scenarios for the year 2000, whereas Belgium and the U.K. externalize their environmental problems in two out of three scenarios for the year 2000. Belgium is actually the only country which can escape the threat it poses to other states if the MFR 2000 scenario became reality.

With respect to ExEmIS2, the GDR also stands out as the country with the highest power to externalize her problem on a per capita base (see Figure 7). Hungary and the CSSR follow with less substantive threats in two out of three scenarios for the year 2000. Regardless of the indicator chosen, the GDR, Hungary, the CSSR, Belgium, and the U.K. remain leading states which externalize an environmental problem.

The previous analyses showed that, as far as acid pollution is concerned, we have a set of net externalizers and a set of net internalizers. Some small countries, like Norway, Sweden, Austria, the Netherlands, and Switzerland, find themselves in an internalizing position. This finding holds if we control for the size of surface area. The GDR is capable of externalizing her acidification problem regardless of the indicator chosen, whereas Belgium, the U.K., the CSSR, and Hungary show minor changes in their their rank order across the export indicators.

3.4 The International Emission Perspective

Rather than looking at international environmental problems from a victim's perspective or an international trade perspective, governments might wish to avoid to be politically targeted *by other countries*. This amounts to asking: What is the threat posed to other countries j by i's emissions? Rather than letting j's government point at i's country, officials in i may wish to (i) anticipate their strategic position and (ii) to conclude that some sort of policy is asked for in order to circumvent foreign policy problems. From this perspective follows that we have to focus on threats by exported emissions.

In the following analyses we will interpret only one scenario as long as *no physical quantities* of sulphur are directly involved in the computation of the indicators. I.e., the concentration indicators for emissions will not vary with the level of emissions since a fixed emission-transport-deposition matrix is underlying these calculations in RAINS. However, once we start to use indicators which combine concentration indices with amounts of sulfur deposited abroad (like ThreatEmIS1, see below), scores for each country will vary *across* scenarios.

If we look at the total emissions of sulphur (see Table 8), the SU, the GDR, the U.K., Poland, and the CSSR would stand out regardless of the scenario chosen. Since we focus on the international part of the problem we have to compute those exported emissions which will be deposited in other EMEP countries. The pecking order does change, with the GDR leading Poland, the CSSR, and the FRG in most scenarios (data not shown here). This change in hierarchy can not only be explained by (i) limiting the analysis to the study of the international aspect of the problem but also by (ii) differences in the amounts of sulphur which *cannot* be allocated to political entities on the receptor' side.

As mentioned above, emissions may pose a problem for one's own country as well as to foreign countries. Roughly 50% of the accountable emissions are deposited on domestic ecosystems. As shown in section 3.2, states turn out be their own predominant adversary. However, the degree of domestic threat varies by country (see Figure 8): The Soviet Union and Turkey deposit roughly 80% and more of their *emissions* domestically.[19] The Mediterranean countries of Spain, Portugal, Greece, and Italy follow in the 60%-70% range whereas Sweden and Norway deposit between 54% and 58% of their emissions domestically. On the other hand, Belgium, The Netherlands, and Denmark deposit between 20% and 30% on their own countries. Figure 8 shows that the Central European countries pose domestic threats to their populations below or at the mean level.

Only 50% of total emissions can be allocated as depositions to political entities within the EMEP area (data not shown here). The remaining 50% of emissions are either

[19] Recall, that only the western parts of these countries are included in the EMEP monitoring area, and limited monitoring makes the scores for these countries susceptible to error.

deposited outside the EMEP area, contribute to background deposition in the EMEP area, or they are deposited on the high seas. Portugal, Ireland, Greece, Norway, and Spain, display higher levels of emissions which *cannot* be accounted for in comparison to a group of states comprising of Hungary, the GDR, Poland, the FRG, Yugoslavia, and Austria. Thus, Central European countries are disproportionately at a disadvantage from an emission perspective, because monitoring holds them more accountable for their emissions than is the case for other countries.

In analogy to section 4.2, we look at the focus (or *concentration*) of the emission stemming from each country i. The Emission Indicator for Sulphur 1 (EmIS1) is defined as

(8) $$EmIS1_i=\sqrt{\sum_{i=1}^{N}(\%w_{ij}\ emissions^2)} \qquad \{i=1,...,j,..,N\}$$

where $\%w_{ij}$ is the % distribution of emissions across all countries (i.e., including domestic deposition). The higher the score on EmIS1, the smaller the number of countries which receive emissions from state i; therefore, country i will be exposed to pressure from fewer countries as the score on EmIS1 increases.

The group of countries consisting of the SU, Turkey, the Iberian countries, Finland and Norway show particularly highly focused emissions, while the Netherlands, Belgium, Austria, the CSSR, Hungary, Denmark, and the GDR display disproportionately low levels of focused emissions (data not shown here).

The indicator EmIS2 only takes into account emissions deposited *abroad*.

(9) $$EmIS2i=\sqrt{\sum_{i=1}^{N}(\%w_{ij}\ emissions^2)} \qquad \{i=1,...,j,..,N;\ i\neq j\}$$

Portugal, Finland, and Ireland are expected to have only *few* foes, because only a small number of countries receive their emissions, whereas the FRG, the SU, the U.K., Italy, France, Yugoslavia, and Austria do pollute a wider array of countries (data not shown here). From an emission perspective, one should expect to find international resistance to country i if (i) its emissions are focused and if (ii) the amount of sulphur exported are high. The indicator of the Threat of Emissions Indicator for Sulphur 1 (ThreatEmIS1) combines theses two components.

(10) $$ThreatEmIS1_i=EmIS2_i \times Exported\ Emissions_i \qquad \{i=1,...,j,..,N\}$$

It turns out (see Figure 9) that the mid-sized East European economies of Poland, the GDR, the CSSR, and Romania are capable to pose foreign threats primarily because of high amounts of exported emissions. This result holds across scenarios. The FRG is capable of reducing its foreign policy vulnerability with the help of its current reduction plans, whereas the U.K., supposedly the "enfant terrible" for many countries, does not occupy a leading position on this threat indicator. On the other end of the spectrum, we find Sweden, Norway, Portugal, Ireland, and Austria. This group comprises of relatively advanced as well as less advanced economies; however all of them belong to the group of "small states" (see section 4) in world politics. Our finding about the East European economies is corroborated, if we introduce the Threat of Emissions Indicator for Sulphur 2 which controls ThreatEmIS1 for population size:

(11) $ThreatEmIS2_i=(ThreatEmIS1_i/Population_i) \times 1{,}000$ $\{i=1,\ldots,j,\ldots,N\}$.

The factor 1,000 is solely introduced for the convenience of readability. On the one hand, the GDR, the CSSR, Hungary, and Poland are able to threaten other states across scenarios (see Figure 10). On the other hand, one can attribute only small international environmental threats to the SU and Turkey in all three scenarios for the year 2000, whereas Sweden, Norway, and Switzerland find themselves in the same position in the OEP 2000 and CRP 2000 scenarios. It has to be mentioned that the CRP 2000 and MFR 2000 scenarios succeed in substantially reducing the mean threat.

In conclusion, we found that states threaten themselves to a substantial degree. The medium range countries on the focus variable EmIS2 (GDR, CSSR, Hungary, Poland) are likely to pose substantial threats through international emissions to other EMEP countries because of the magnitude of exported emissions (GDR, CSSR, Poland). From an emission perspective, we do expect these three countries to be at the core of the problem of sulphur-based acidification in the European member states of the UNECE.

4. Theoretical Implications of the Findings and an Agenda for Future Research

This concluding section will summarize and integrate our findings, point at potential methodological improvements, and reinterprets some world politics terminology in view of our findings.

A short look at Table 9 highlights two interesting clusters of states: (i) a group of "small countries", which find themselves in a disadvantageous position, and (ii) a group of East European countries.

With respect to the deposition perspective, "small" states, defined as states which cannot influence their environmental vulnerability to a substantial degree,[20] find themselves either in an exposed position or in a "safe" position. Austria and the Netherlands appear to be quite vulnerable, which is not true for Finland, Ireland, and Portugal. However, a set of small countries comprising Sweden, Norway, Austria, Switzerland are net internalizers of the internationalized problem of acidification ("trade perspective"), and they do not cause substantial international threats with their emissions.

Although the GDR and the CSSR find themselves threatened from a deposition perspective, they are able to externalize part of their international problem. Together with Poland, these countries are likely to face demands from other countries for ameliorative action. However, we shall not assume that these countries will undertake drastic policies to combat their domestic or international problem, because it is unlikely that Eastern European countries can easily afford it on their own.

This paper developed some indictors of international environmental threats involving transboundary acid pollution. Future analyses will include acidification caused by nitrogen oxides. The TAP project at IIASA is currently updating the relevant database. In the future, the author will undertake additional analyses in order to see (i) how close our indicators are related to each other and (ii) to what degree they form separate dimensions. In addition, indicators will be developed, which summarize the domestic and international problem of acidification for each country. Ecosystem sensitivity measures will be incorporated in order to more accurately define international vulnerability; furthermore, indicators of the costs for specific policy scenarios will have to be incorporated in the analysis. Then we may determine the range of possible political outcomes (see Stam et al 1989).

This analysis also taught us some lessons for international relations theory. The term "international interdependence" (Keohane/Nye 1977) certainly does not point to mutual dependence of the 25 countries of Europe. Quite to the contrary, countries are often only dependent on their immediate neighbors, and the extent of dependence varies with (i) the amount to which the problem is domestically caused and with (ii) the country-specific emitter-receptor matrix. Foreign policies and domestic policies are therefore related. In order to achieve environmental security, governments have to persuade domestic and foreign polluters.

Furthermore, the international aspect of the acidification problem cannot be derived from a transitivity property of the international system: If i depends on j, and if j depends on k, transitivity postulates that i will depend on k. However, this is unlikely to be the case with transboundary acidification. Instead, we should think of this

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[20] In international trade theory, small economies are price-takers, whereas large economies can influence the terms-of-trade.

environmental problem as a set of "overlapping umbrellas": Each state tries to protect itself with an umbrella. Since each country tries to do so (although umbrella quality does vary with the degree of environmental quality preferred), all of Europe is covered by umbrellas. However, umbrellas are put up at different heights so as to display different degrees of willingness to solve the problem. Some clusters of umbrellas are put higher because a country is advantaged by its relative, structural position (less vulnerability), or because it has less preferences for a safe environment. Other clusters of umbrellas are located closer to the earth's surface and symbolize strong preferences for environmental protection. Domestic politics has to be incorporated in the analysis, since it might be an important factor in determining where nations put their umbrellas (see Figure 1).

What is the role of international organizations with regard to regulating acid pollution? One country may be interested in bribing another country because this can be the least costly method for reducing depositions in one's country (i.e., "bring its umbrella closer to the earth's surface"). International organizations may be able to fine-tune the arrangement of the umbrellas so as to find efficient sets of coordinated umbrella configurations. Thus, economic efficiency might be supported through the foundation of a "common fund". This fund would possibly be established so as to finance European clean-up efforts through disproportionately large contributions from the "West" and relatively small contributions from the "East". However, it shall not be overlooked that there might be strong incentives for some countries *not to give to all other countries equally* but to assure one's *own* national environmental security. The larger the sums involved, the more likely we will find influential donators to tie their help to specific emission reductions in countries of their choice[21]. Assuming the "West" wishes to "buy" environmental security, it is likely that it will not care much for the problem of achieving similar deposition goals in some Eastern European countries ("common environmental security") because of the enormous costs involved. Rather than showing benevolence, we could (but not have to) find that the international negotiations process will coordinate institutionalized international bribery between clusters of states, and international organizations simply serve as a forum for rule interpretation, "political" litigation, administration of the fund, and "soft" enforcement of the agreements. Actually, it could be interesting for the "West" to coordinate its bribing efforts so as to achieve their environmental goal in the least expensive way. This assumes that the West European countries will be able to overcome national egoisms which is the more likely, the more similar the "Western" countries are with respect to their position within the international environmental structure.

Self-help in the international environmental system is unlikely to include force, because it is foreign energy policies, foreign transportation policies, etc., which a state may wish to change. The "power" of a country, or her "influence", would be expressed as its

[21] This phenomenon can partially be observed with debt-for-nature swaps (Page 1989).

capacity to determine other countries' energy policy. Unlike in the sphere of military security, the willingness and the capability to transfer resources to other countries (or to offer alternative kinds of compensation) is a necessary condition for country j's might. Only few states are likely to be able do this.

The international environmental system with regard to the acidification problem in Europe is asymmetrical. Clusters of states can be distinguished, and international organizations might be helpful in achieving environmental goals more cost-efficiently. However, I suspect that the problem at hand gives states incentives to solve problems unilaterally or in small groups. Although the pecking order within the international environmental structure might be very stable, coordinated remedial action will lead to a reduction of the environmental threat to all countries in Europe.

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Tables

Table 1: Official Energy Pathway 1980 (OEP 1980)

Emitter Countries> / Recipients >	AL	A	B	BG	CS	DK	SF	F	D	DDR	GR	H	IRL	I	L	NL	N	PL	P	R	E	S	CH	TR	UK	SU	YU
AL	7	0	0	3	1	0	0	1	1	1	4	1	0	4	0	0	0	1	0	1	1	0	0	0	1	2	4
A	0	32	2	1	35	0	0	13	24	24	0	19	0	29	0	1	0	15	0	2	2	0	2	0	5	4	16
B	0	0	48	0	2	0	0	45	35	4	0	0	0	1	1	10	0	1	0	0	1	0	0	0	15	1	0
BG	1	1	0	126	6	0	0	1	2	5	6	7	0	4	0	0	0	7	0	35	1	0	0	3	2	11	11
CS	0	14	4	1	306	1	0	14	39	141	0	64	0	11	0	2	0	135	0	5	2	0	1	0	9	6	10
DK	0	0	2	0	4	22	0	3	13	13	0	1	0	1	0	2	0	5	0	0	0	3	0	0	11	2	0
SF	0	0	1	1	6	2	79	3	6	12	0	2	0	2	0	1	1	11	0	1	2	10	0	0	7	67	1
F	0	3	49	2	21	1	1	558	73	36	1	6	2	59	2	9	0	15	1	2	76	1	8	1	76	18	4
D	0	9	47	1	61	6	0	116	400	156	1	8	1	24	2	26	0	26	0	2	7	1	6	0	59	9	5
DDR	0	2	9	0	127	4	0	18	96	518	0	4	0	5	0	5	0	39	0	1	1	1	0	0	19	4	2
GR	4	0	0	28	3	0	0	2	2	3	79	3	0	7	0	0	0	3	0	4	2	0	0	3	1	5	5
H	0	9	1	2	45	0	0	5	7	16	1	173	0	14	0	0	0	22	0	18	1	0	0	0	3	4	32
IRL	0	0	1	0	1	0	0	2	2	1	0	0	19	1	0	0	0	1	0	0	1	0	0	0	16	3	0
I	1	6	3	3	12	0	0	35	14	13	3	10	0	554	0	1	0	10	0	3	13	0	6	1	8	10	17
L	0	0	2	0	0	0	0	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
NL	0	0	24	0	3	0	0	14	59	6	0	1	0	1	0	24	0	2	0	0	1	0	0	0	20	1	0
N	0	0	3	1	8	6	2	7	12	19	1	2	1	4	0	2	14	11	0	1	3	8	0	1	22	20	1
PL	0	6	8	2	176	7	1	18	58	305	1	35	0	11	0	5	0	630	0	8	2	3	0	1	23	23	9
P	0	0	0	0	1	0	0	2	1	1	0	0	0	1	0	0	0	1	26	0	18	0	0	0	2	3	0
R	0	2	1	26	31	1	0	5	8	23	3	56	0	12	0	1	0	37	0	233	2	0	0	2	5	34	30
E	0	1	2	1	5	0	0	35	8	8	1	2	0	8	0	1	0	5	10	1	415	0	0	1	12	10	1
S	0	1	4	1	16	21	10	10	23	40	1	4	0	5	0	3	7	27	0	2	3	59	0	1	24	25	2
CH	0	2	2	0	4	0	0	23	10	5	0	1	0	50	0	1	0	2	0	0	3	0	11	0	4	2	1
TR	0	0	1	20	4	0	0	3	3	5	13	4	0	5	0	0	0	5	0	6	2	0	0	97	3	22	3
UK	0	0	8	1	5	1	0	23	13	10	0	1	8	3	0	4	0	5	0	1	5	1	0	0	528	7	1
SU	1	7	11	27	129	14	47	33	70	185	9	74	1	35	0	7	2	291	1	95	17	18	1	10	57	2142	25
YU	6	12	2	42	26	1	0	12	12	21	7	68	0	72	0	1	0	21	0	27	5	0	1	2	6	13	182

Units: Annual S-deposition in kilotons

Source-receptor matrices used: Average of tot1979, tot1980, tot1983, tot1984

Data were derived from the Regional Acidification and INformation and Simulation model (RAINS) developed by the International Institute for Applied Systems Analysis (IIASA) (see Alcamo et al 1988).

Table 2: Official Energy Pathway 2000 (OEP 2000)

Emitter Countries>	AL	A	B	BG	CS	DK	SF	F	D	DDR	GR	H	IRL	I	L	NL	N	PL	P	R	E	S	CH	TR	UK	SU	YU
Recipients >AL	15	0	0	4	1	0	0	0	1	1	11	1	0	3	0	0	0	1	0	2	1	0	0	1	1	2	11
A	0	33	2	1	26	0	0	6	22	23	1	18	0	22	0	1	0	15	0	3	2	0	2	0	5	4	41
B	0	0	34	0	2	0	0	21	31	4	0	0	0	1	1	10	0	1	0	0	1	0	0	0	13	1	1
BG	2	1	0	178	4	0	0	1	2	5	16	7	0	3	0	0	0	6	0	54	1	0	0	8	1	11	30
CS	0	14	3	2	228	1	0	7	35	138	1	61	0	9	0	2	0	133	0	8	2	0	1	1	8	6	26
DK	0	0	1	0	3	20	0	1	12	12	0	1	0	1	0	2	0	5	0	0	0	2	0	0	0	2	1
SF	0	0	1	1	4	2	59	2	6	12	1	2	0	2	0	1	1	11	0	2	2	8	0	1	6	67	2
F	0	3	35	2	15	1	1	266	65	36	3	5	2	45	4	9	0	15	1	4	77	1	6	3	67	18	11
D	0	9	33	1	46	6	0	55	359	153	1	7	1	18	4	28	0	25	0	3	7	1	5	1	52	9	13
DDR	0	2	6	0	95	4	0	9	86	509	1	4	0	4	0	6	0	38	0	1	1	1	0	0	17	4	4
GR	8	0	0	40	2	0	0	1	1	3	216	3	0	5	0	0	0	2	0	6	2	0	0	8	1	5	13
H	0	9	1	3	33	0	0	2	6	15	1	164	0	11	0	0	0	22	0	28	1	0	0	1	3	4	83
IRL	0	0	0	0	1	0	0	1	1	1	0	0	23	1	0	0	0	1	0	0	1	0	0	0	15	3	1
I	2	6	2	5	9	0	0	17	13	12	7	9	0	428	0	1	0	10	0	4	14	0	5	2	7	10	44
L	0	0	1	0	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
NL	0	0	17	0	2	0	0	7	53	6	0	0	0	1	0	26	0	2	0	0	1	0	0	0	18	1	1
N	0	0	2	1	6	5	2	3	11	19	2	2	1	3	0	2	14	11	0	2	3	6	0	2	20	19	3
PL	0	6	5	3	131	6	1	9	52	299	2	33	0	9	0	5	0	619	0	13	2	2	0	1	21	23	22
P	0	0	0	0	1	0	0	1	1	1	0	0	0	1	0	0	0	1	34	0	19	0	0	0	2	2	1
R	1	2	1	37	23	1	0	2	7	23	8	53	0	9	0	1	0	37	0	362	2	0	0	6	4	34	77
E	0	1	2	1	4	0	0	17	8	8	2	2	0	6	0	1	0	5	13	2	423	0	0	1	10	10	3
S	0	1	3	2	12	19	8	5	21	40	2	4	1	4	0	3	8	26	0	3	3	45	0	2	21	25	5
CH	0	2	1	0	3	0	0	11	9	5	0	1	0	39	0	1	0	2	0	0	3	0	9	0	3	2	3
TR	1	0	0	28	3	0	0	1	2	5	37	4	0	4	0	0	0	5	0	9	2	0	0	269	3	22	9
UK	0	0	6	1	3	1	0	11	11	10	1	1	9	2	0	4	0	5	0	1	5	0	0	1	468	7	2
SU	2	7	8	38	96	13	36	16	63	182	24	70	2	27	0	7	2	286	2	148	18	14	1	29	50	2137	66
YU	11	12	1	59	19	0	0	6	11	21	20	64	0	56	0	1	0	21	0	42	5	0	1	5	5	13	470

Units: Annual S-deposition in kilotons

Source-receptor matrices used: Average of tot1979, tot1980, tot1983, tot1984

Data were derived from the Regional Acidification and INformation and Simulation model (RAINS) developed by the International Institute for Applied Systems Analysis (IIASA) (see Alcamo et al 1988).

Table 3: Current Reduction Plans 2000 (CRP 2000)

Emitter Countries>	AL	A	B	BG	CS	DK	SF	F	D	DDR	GR	H	IRL	I	L	NL	N	PL	P	R	E	S	CH	TR	UK	SU	YU
Recipients > AL	15	0	0	2	1	0	0	0	0	1	11	1	0	3	0	0	0	1	0	2	1	0	0	1	0	1	11
A	0	10	2	0	25	0	0	6	8	17	1	13	0	20	0	0	0	15	0	3	2	0	1	0	4	2	41
B	0	0	34	0	1	0	0	22	12	3	0	0	0	1	0	5	0	1	0	0	1	0	0	0	10	1	1
BG	2	0	0	88	4	0	0	1	1	4	16	5	0	3	0	0	0	6	0	54	1	0	0	8	1	8	30
CS	0	4	3	1	214	1	0	7	14	99	1	45	0	8	0	1	0	133	0	8	2	0	0	1	6	4	26
DK	0	0	1	0	3	11	0	2	5	9	0	0	0	1	0	1	0	5	0	0	0	1	0	0	8	1	1
. SF	0	0	1	1	4	1	39	2	2	9	1	1	0	2	0	0	1	11	0	2	2	4	0	1	5	47	2
F	0	1	34	1	15	1	0	279	25	25	3	4	2	41	1	4	0	15	1	4	77	0	4	3	53	13	11
D	0	3	33	1	43	3	0	58	140	109	1	5	1	17	1	13	0	25	0	3	7	0	3	1	41	6	13
DDR	0	0	6	0	89	2	0	9	34	363	1	3	0	3	0	3	0	38	0	1	1	0	0	0	14	3	4
GR	8	0	0	20	2	0	0	1	1	2	216	2	0	5	0	0	0	2	0	6	2	0	0	8	1	4	13
H	0	3	1	1	31	0	0	2	3	11	1	121	0	10	0	0	0	22	0	28	1	0	0	1	2	3	83
IRL	0	0	0	0	1	0	0	1	1	1	0	0	23	1	0	0	0	1	0	0	1	0	0	0	12	2	1
I	2	2	2	2	8	0	0	18	5	9	7	7	0	388	0	1	0	10	0	4	14	0	3	2	6	7	44
L	0	0	1	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NL	0	0	17	0	2	0	0	7	21	4	0	0	0	0	0	12	0	2	0	0	1	0	0	0	14	1	1
N	0	0	2	1	5	3	1	4	4	13	2	1	1	3	0	1	7	11	0	2	3	3	0	2	16	14	3
PL	0	2	5	1	123	4	1	9	20	214	2	24	0	8	0	2	0	619	0	13	2	1	0	1	16	16	22
P	0	0	0	0	1	0	0	1	0	1	0	0	0	1	0	0	0	1	34	0	19	0	0	0	1	2	1
R	1	1	1	18	22	0	0	2	3	16	8	39	0	9	0	0	0	37	0	362	2	0	0	6	3	24	77
E	0	0	2	1	4	0	0	17	3	6	2	1	0	5	0	0	0	5	13	2	423	0	0	1	8	7	3
S	0	0	3	1	11	10	5	5	8	28	2	3	1	3	0	1	4	26	0	3	3	21	0	2	17	18	5
CH	0	0	1	0	2	0	0	11	4	3	0	1	0	35	0	0	0	2	0	0	3	0	6	0	3	1	3
TR	1	0	0	14	3	0	0	1	1	3	37	3	0	4	0	0	0	5	0	9	2	0	0	269	2	16	9
UK	0	0	6	0	3	1	0	11	4	7	1	1	9	2	0	2	0	5	0	1	5	0	0	1	370	5	2
SU	2	2	8	19	90	7	24	17	25	130	24	52	2	25	0	3	1	286	2	148	18	6	0	29	40	1499	66
YU	11	3	1	29	18	0	0	6	4	15	20	47	0	51	0	0	0	21	0	42	5	0	0	5	4	9	470

Units: Annual S-deposition in kilotons

Source-receptor matrices used: Average of tot1979, tot1980, tot1983, tot1984

Data were derived from the Regional Acidification and INformation and Simulation model (RAINS) developed by the International Institute for Applied Systems Analysis (IIASA) (see Alcamo et al 1988).

Table 4: Maximum Feasible Reductions 2000 (MFR 2000)

Emitter Countries>	AL	A	B	BG	CS	DK	SF	F	D	DDR	GR	H	IRL	I	L	NL	N	PL	P	R	E	S	CH	TR	UK	SU	YU
Recipients > AL	3	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
A	0	6	0	0	7	0	0	1	3	4	0	4	0	3	0	0	0	4	0	0	0	0	1	0	1	1	7
B	0	0	4	0	0	0	0	4	5	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0
BG	0	0	0	22	1	0	0	0	0	1	2	2	0	0	0	0	0	2	0	9	0	0	0	2	0	2	5
CS	0	3	0	0	58	0	0	1	5	25	0	14	0	1	0	0	0	40	0	1	0	0	0	0	1	1	5
DK	0	0	0	0	1	3	0	0	2	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0
SF	0	0	0	0	1	0	11	0	1	2	0	0	0	0	0	0	0	3	0	0	0	2	0	0	1	12	0
F	0	1	4	0	4	0	0	54	10	7	0	1	0	5	0	1	0	4	0	1	10	0	3	1	9	3	2
D	0	2	4	0	12	1	0	11	55	28	0	2	0	2	0	4	0	8	0	0	1	0	2	0	7	2	2
DDR	0	0	1	0	24	0	0	2	13	94	0	1	0	0	0	1	0	12	0	0	0	0	0	0	2	1	1
GR	2	0	0	5	1	0	0	0	0	0	26	1	0	1	0	0	0	1	0	1	0	0	0	2	0	1	2
H	0	2	0	0	9	0	0	0	1	3	0	39	0	1	0	0	0	7	0	5	0	0	0	0	0	1	15
IRL	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	2	0	0
I	0	1	0	1	2	0	0	3	2	2	1	2	0	50	0	0	0	3	0	1	2	0	3	1	1	2	8
L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NL	0	0	2	0	1	0	0	1	8	1	0	0	0	0	0	3	0	1	0	0	0	0	0	0	2	0	0
N	0	0	0	0	1	1	0	1	2	3	0	0	0	0	0	0	4	3	0	0	0	1	0	1	3	3	1
PL	0	1	1	0	34	1	0	2	8	55	0	8	0	1	0	1	0	187	0	2	0	1	0	0	3	4	4
P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	2	0	0	0	0	0	0
R	0	0	0	5	6	0	0	0	1	4	1	13	0	1	0	0	0	11	0	58	0	0	0	2	1	6	14
E	0	0	0	0	1	0	0	3	1	2	0	0	0	1	0	0	0	1	1	0	56	0	0	0	1	2	1
S	0	0	0	0	3	3	1	1	3	7	0	1	0	0	0	0	2	8	0	0	0	11	0	1	3	4	1
CH	0	0	0	0	1	0	0	2	1	1	0	0	0	5	0	0	0	1	0	0	0	0	5	0	0	0	1
TR	0	0	0	4	1	0	1	0	0	1	4	1	0	0	0	0	0	2	0	2	0	0	0	81	0	4	2
UK	0	0	1	0	1	0	0	2	2	2	0	0	2	0	0	1	0	1	0	0	1	0	0	0	61	1	0
SU	0	1	1	5	25	2	7	3	10	34	3	16	0	3	1	1	1	87	0	24	2	3	0	9	7	373	12
YU	2	2	0	7	5	0	0	1	2	4	2	15	0	7	0	0	0	6	0	7	1	0	0	1	1	2	85

Units: Annual S-deposition in kilotons

Source-receptor matrices used: Average of tot1979, tot1980, tot1983, tot1984

Data were derived from the Regional Acidification and INformation and Simulation model (RAINS) developed by the International Institute for Applied Systems Analysis (IIASA) (see Alcamo et al 1988).

Table 5: Emission Data for OEP 1980 and CRP 2000
(As Published by the UNECE)

Country	OEP 1980	CRP 2000
AL	25	50
A	177	53
B	414	235
BG	517	362
CS	1550	1070
DK	225	96
SF	292	139
F	1775	760
D	1600	500
DDR	2500	1750
GR	200	933
H	817	570
IRL	110	126
I	1900	1185
L	12	5
NL	232	107
N	71	35
PL	2050	2450
P	133	163
R	100	237
E	1625	1527
S	251	78
CH	63	29
TR	138	276
UK	2420	1525
SU	6400	4450
Yu	588	1290

source: UNECE 1989, 7

Note: All entries are integers, expressed in kt of sulphur

Table 6: Deposition of Sulphur/Area [g/m²/year]

Country	OEP 1980	OEP 2000	CRP 2000	MFR 2000
A	2.69	2.70	2.02	0.50
B	5.29	3.90	2.97	0.55
BG	2.06	2.97	2.09	0.43
CS	5.98	5.36	4.52	1.21
DK	1.91	1.47	1.14	0.26
SF	0.64	0.57	0.41	0.10
F	1.87	1.27	1.13	0.22
D	3.91	3.36	2.12	0.57
DDR	7.92	7.33	5.31	1.41
GR	1.17	2.39	2.22	0.33
H	3.80	4.16	3.48	0.89
IRL	0.69	0.70	0.64	0.09
I	2.40	2.02	1.80	0.28
NL	3.80	3.29	2.00	0.46
N	0.46	0.43	0.31	0.07
PL	4.26	4.04	3.53	1.00
P	0.61	0.70	0.67	0.05
R	2.15	2.90	2.65	0.52
E	1.04	1.03	1.00	0.14
S	0.64	0.58	0.40	0.11
CH	2.95	2.29	1.83	0.41
TR	0.43	0.88	0.82	0.22
UK	2.56	2.25	1.79	0.31
SU	0.98	0.99	0.75	0.19
YU	2.11	3.29	2.97	0.59
Min	0.43	0.43	0.31	0.05
Max	7.92	7.33	5.31	1.41
Mean	2.49	2.43	1.94	0.44
S.D.	1.91	1.70	1.31	0.36

Table 7: Net Sulphur Imports by Country [kt S/year]

Country	OEP 1980	OEP 2000	CRP 2000	MFR 2000
A	119	119	139	23
B	-71	-44	-72	-1
BG	-60	-77	31	-2
CS	-273	-86	-147	-44
DK	-5	-16	5	0
SF	75	86	68	13
F	19	215	116	28
D	-21	-55	178	8
DDR	-716	-751	-528	-131
GR	23	-41	-64	3
H	-193	-129	-55	-37
IRL	16	10	6	0
I	-200	-107	-108	4
NL	50	24	33	6
N	125	114	89	17
PL	4	-41	-200	-81
P	18	14	12	1
R	64	-7	-66	12
E	-59	-79	-95	-5
S	184	183	144	31
CH	85	64	58	3
TR	73	62	37	2
UK	-314	-273	-221	-34
SU	861	903	811	205
YU	177	-100	-182	-20
Min	-716	-751	-528	-131
Max	861	903	811	205
Mean	-1	0	0	0
S.D.	261	262	226	55

Note: Negative entries reflect a net exporter position.

Table 8: Total Emissions of Sulphur [kt S/year] (Computed by RAINS)

Country	OEP 1980	OEP 2000	CRP 2000	MFR 2000
A	177	177	53	34
B	428	302	300	38
BG	514	726	360	91
CS	1573	1171	1101	301
DK	225	205	112	28
SF	292	221	146	41
F	1775	847	887	173
D	1600	1436	560	221
DDR	2398	2353	1679	434
GR	398	1090	1090	130
H	816	772	571	182
IRL	108	127	127	22
I	1805	1397	1263	165
NL	232	244	116	33
N	69	71	35	20
PL	2055	2019	2019	611
P	134	178	178	16
R	753	1170	1170	188
E	1627	1657	1657	220
S	241	184	84	44
CH	64	52	32	26
TR	335	936	936	282
UK	2338	2070	1637	271
SU	6476	6462	4534	1128
YU	591	1526	1526	276
Min	64	52	32	16
Max	6476	6462	4534	1128
Mean	1081	1096	887	199
S.D.	1367	1319	990	243

Table 9: Summary of Findings

Indicator	Vulnerable Countries	Not Vulnerable Countries
Depositions	**Vulnerable Countries**	**Not Vulnerable Countries**
ThreatDepIS	A, B, CS, D,	SF, IRL, P, E
	DDR, NL	TR, UK
International Trade	**Internalizing Countries**	**Externalizing Countries**
ImDepIS1	N, CH, S, A	--
ImDepIS2	NL, CH, S, A	--
ExEmIS1	--	DDR, B, UK
ExEmIS2	--	DDR, H, CS
Emissions	**Vulnerable Countries**	**Not Vulnerable Countries**
ThreatEmIS1	DDR, PL, CS	S, N, P, IRL, A
ThreatEmIS2	DDR, CS, H, PL	SU, TR, S, N, CH

Figures

Figure 1: A Model of International Environmental Regulation

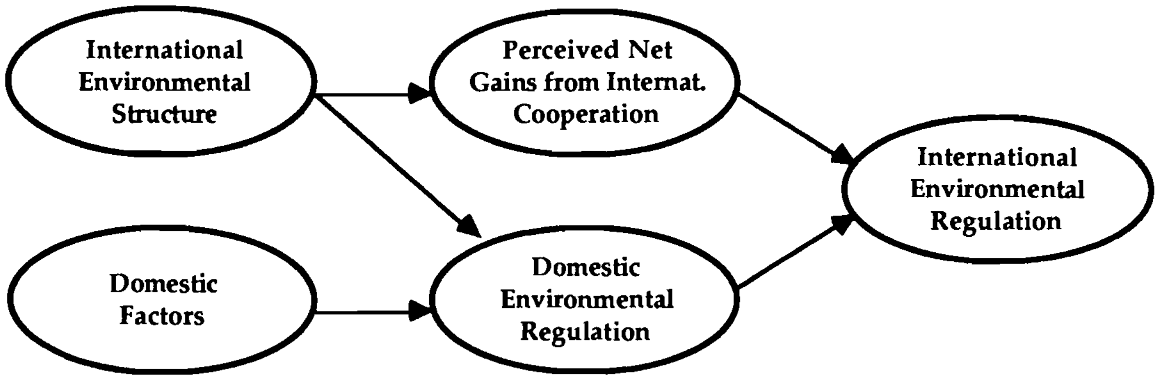
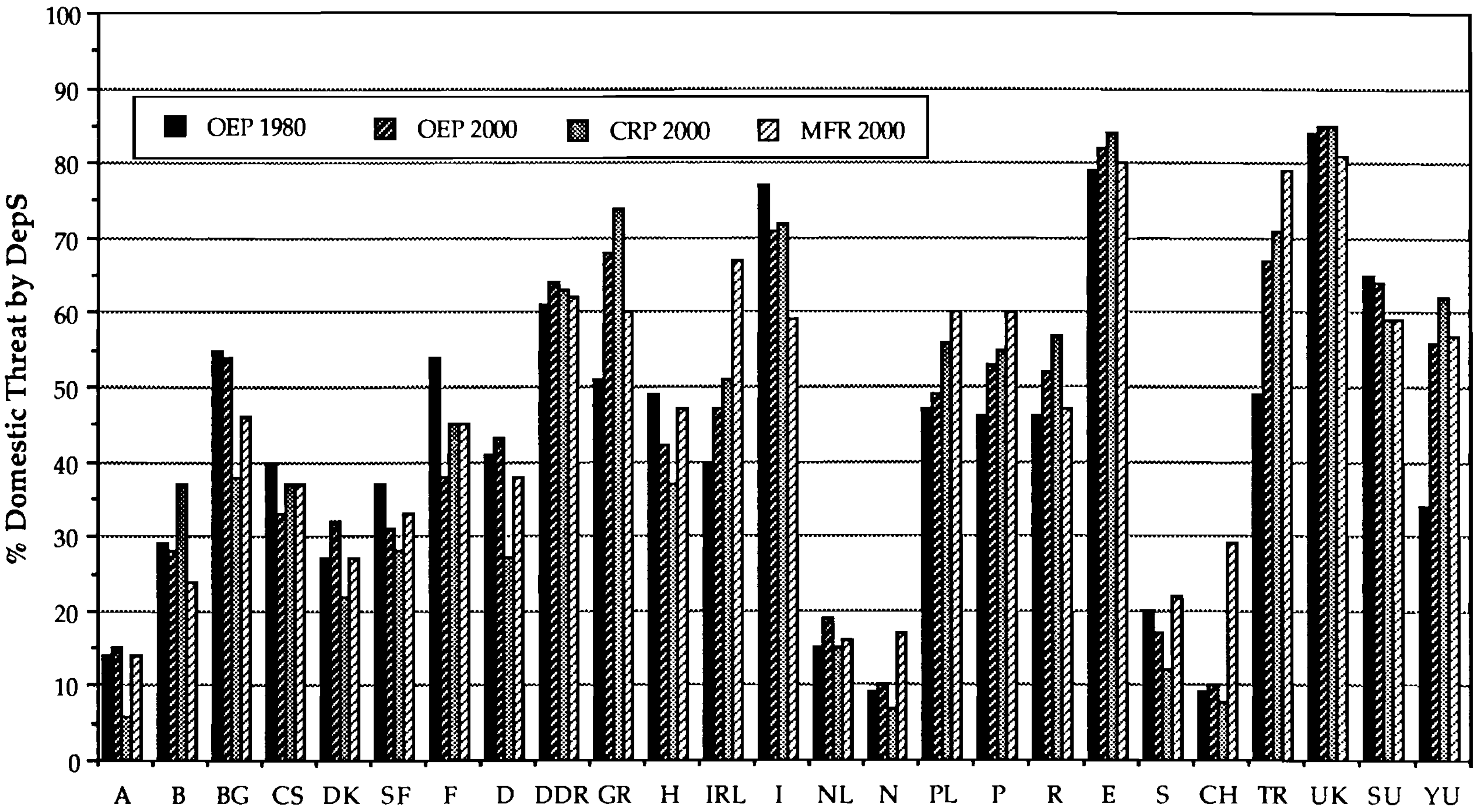


Figure 2: % Domestic Contributions to Accountable Sulphur Depositions



<u>Figure 3:</u> Foreign Caused Threats to Deposition - ThreatDepIS
(adjusted for surface area)

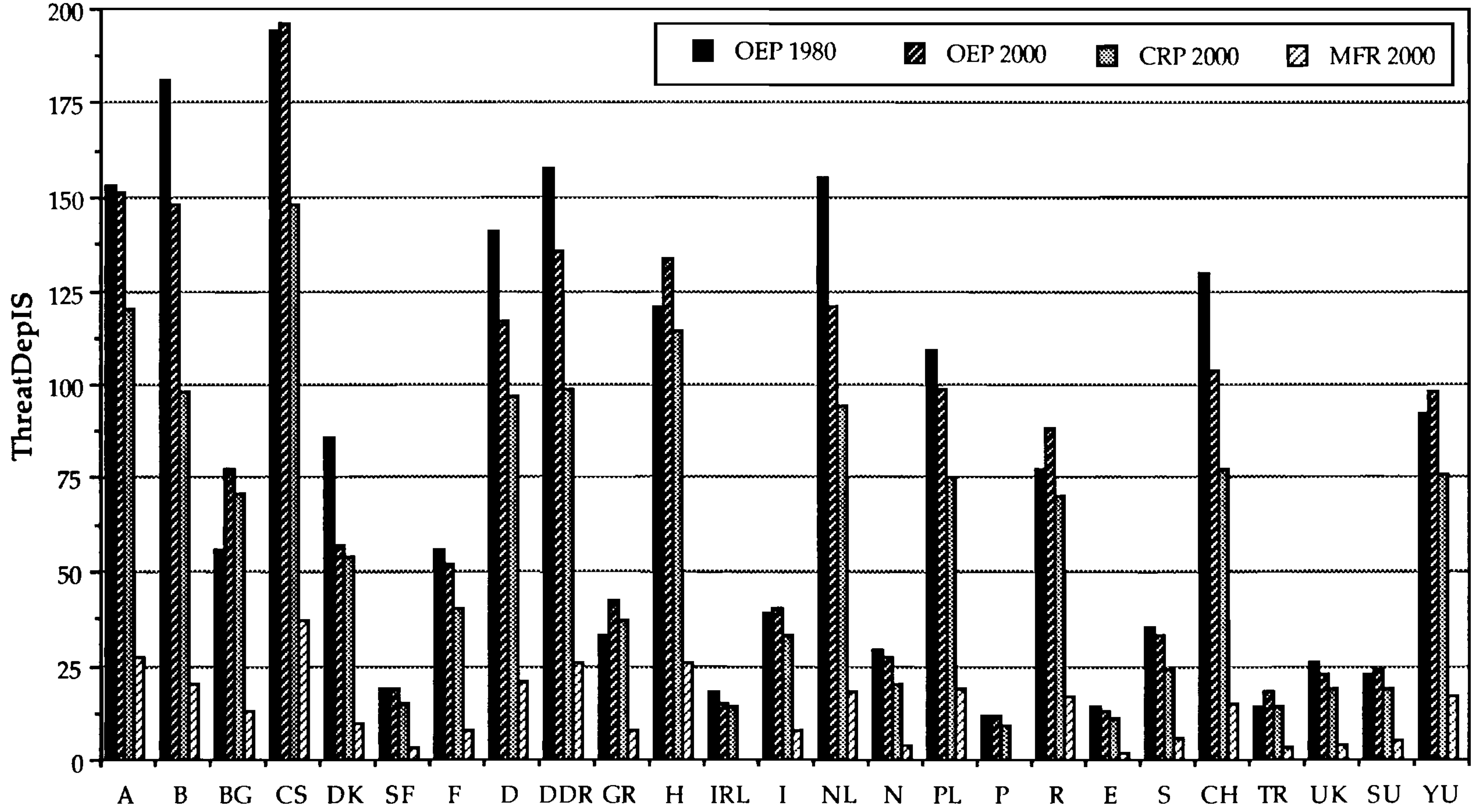


Figure 4: An Indicator of Net Internalization of International Acidification - ImDepIS1

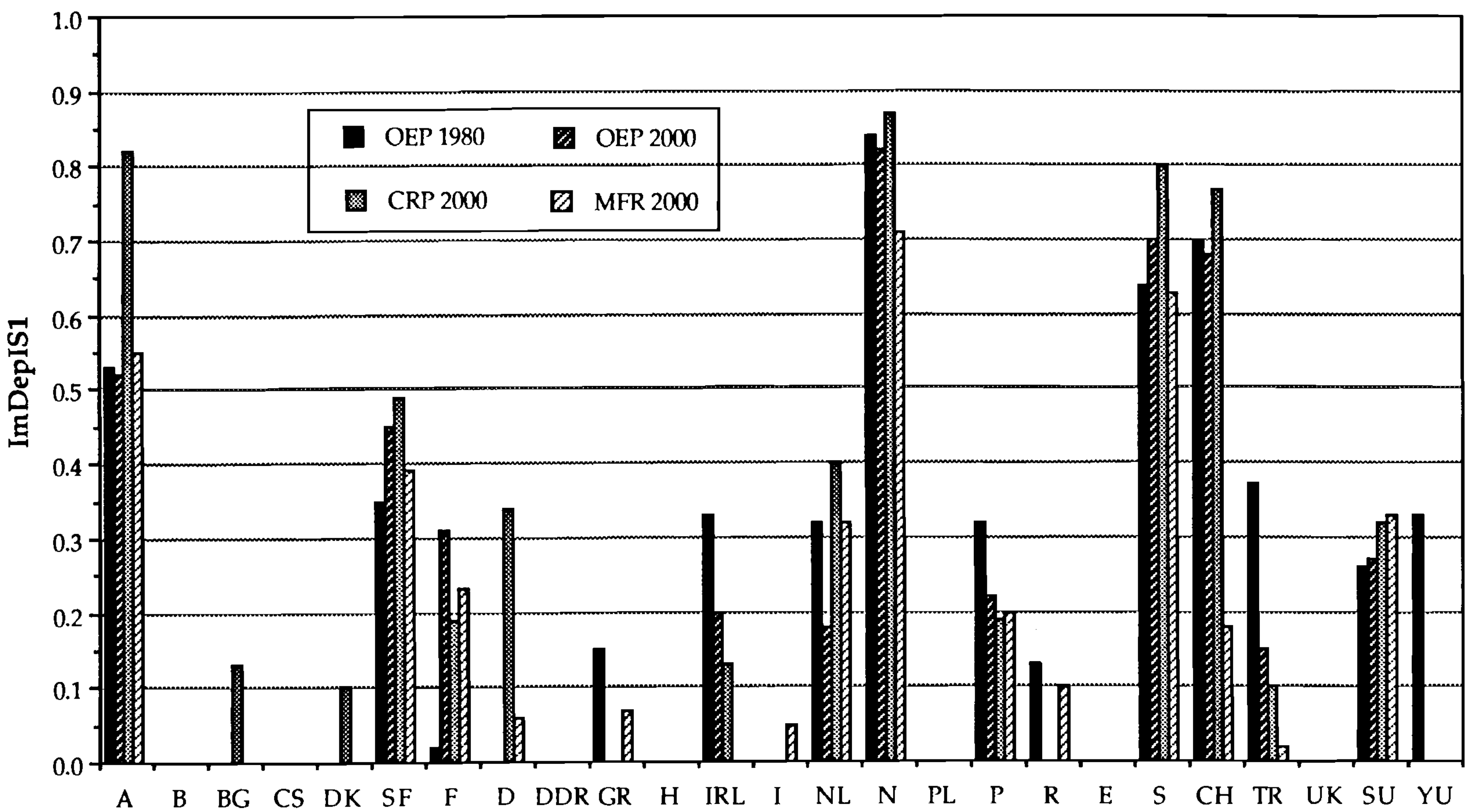
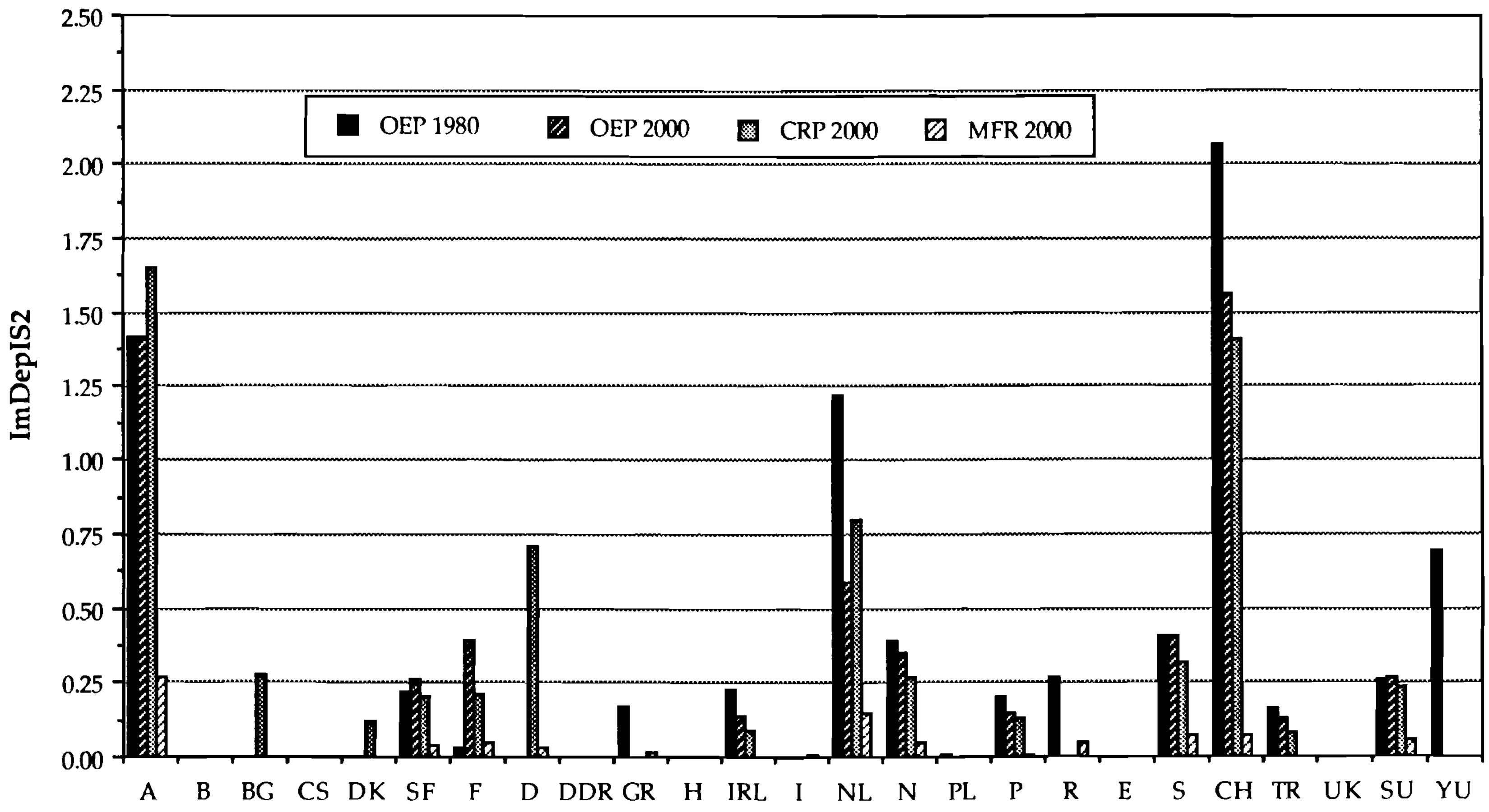


Figure 5: Net Internalization of International Acidification - ImDepIS2 [g/m²/year]
(adjusted for surface area)



<u>Figure 6:</u> An Indicator of Net Externalization of International Acidification - ExEmIS1

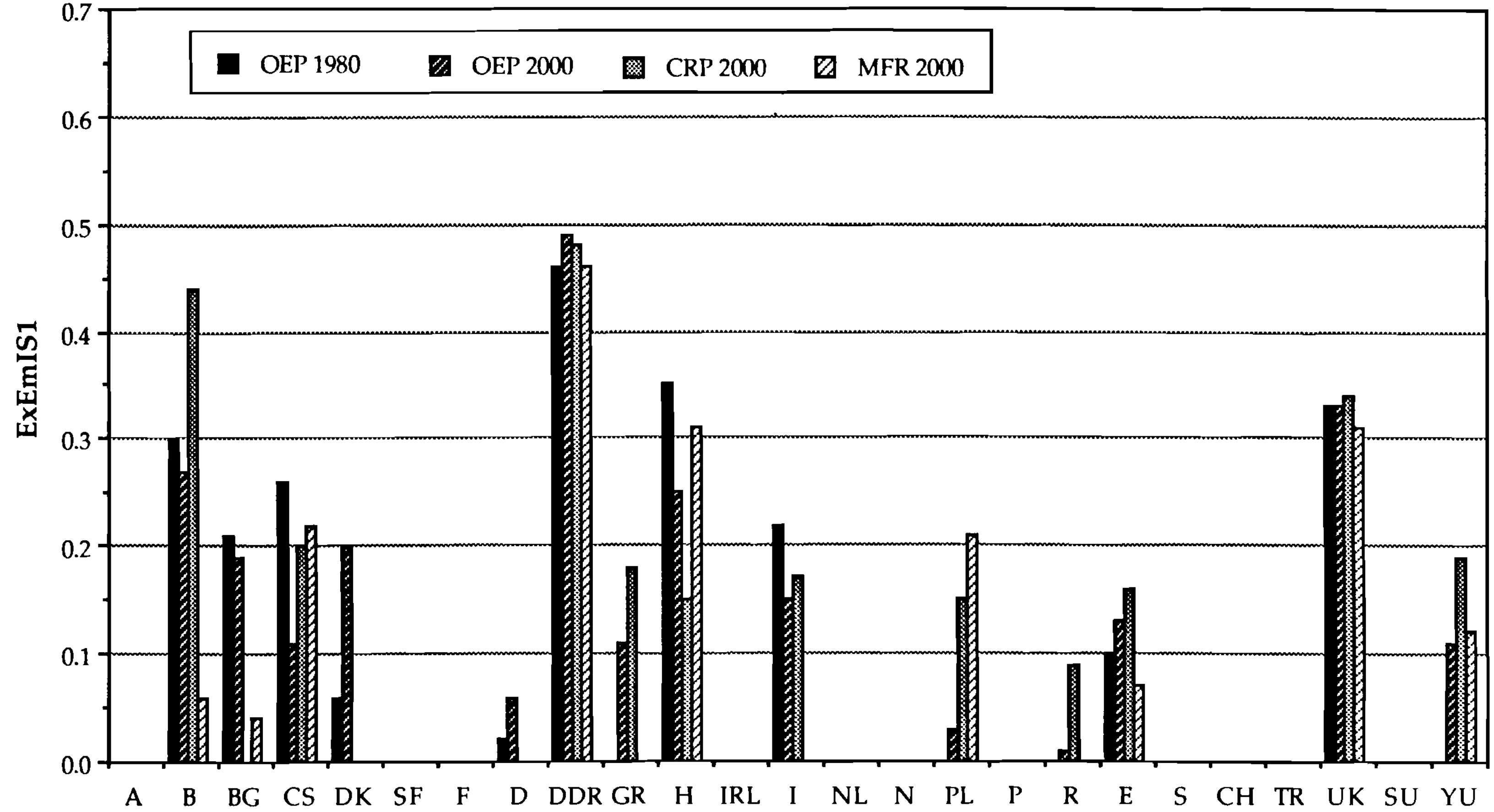


__Figure 7:__ **Net Externalization of International Acidification - ExEmIS2 (adjusted for population size in 1980)**

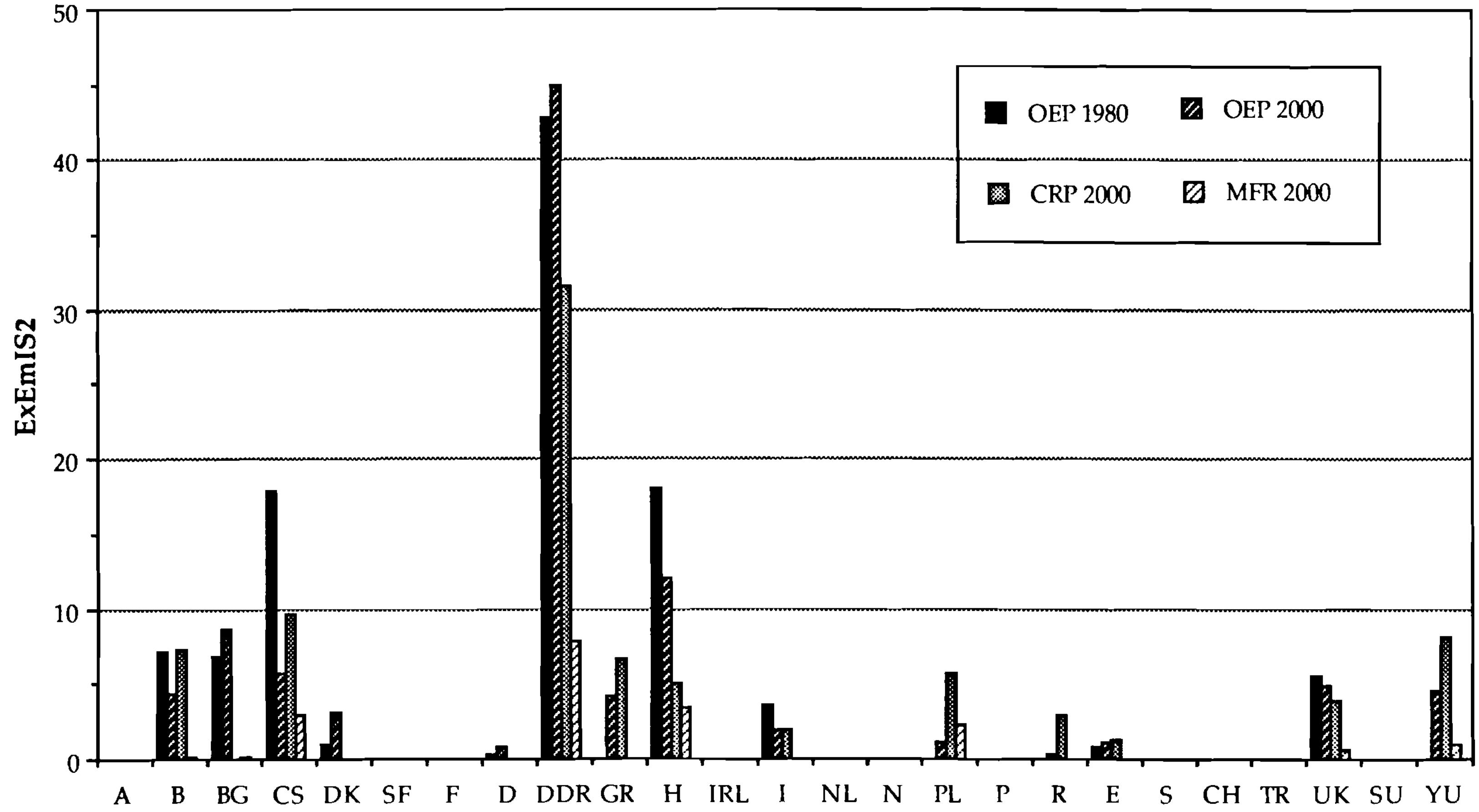
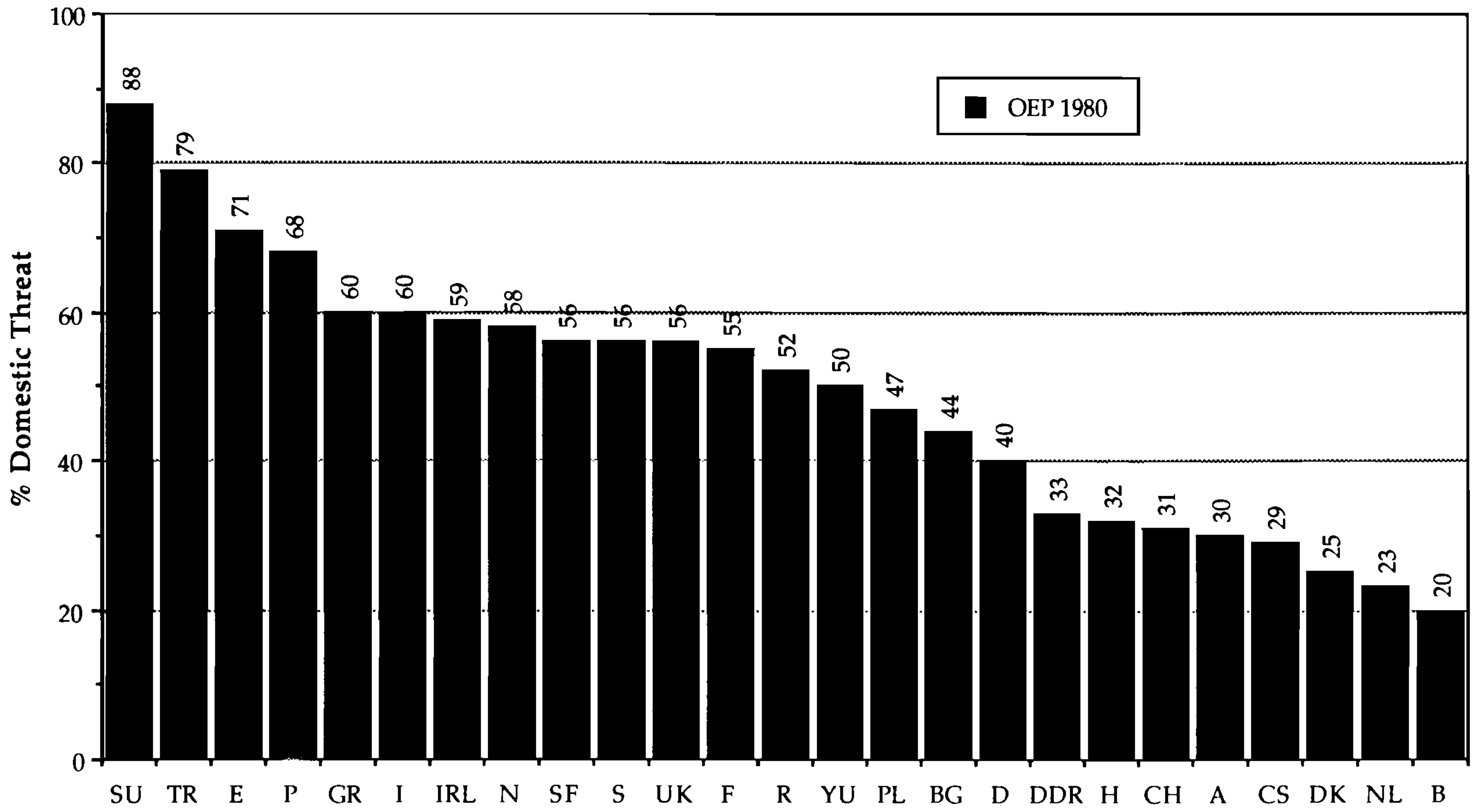


Figure 8: % Domestic Threat Through National Emissions (OEP 1980)



<u>Figure 9:</u> Exported Threats from Emissions - ThreatEmIS1

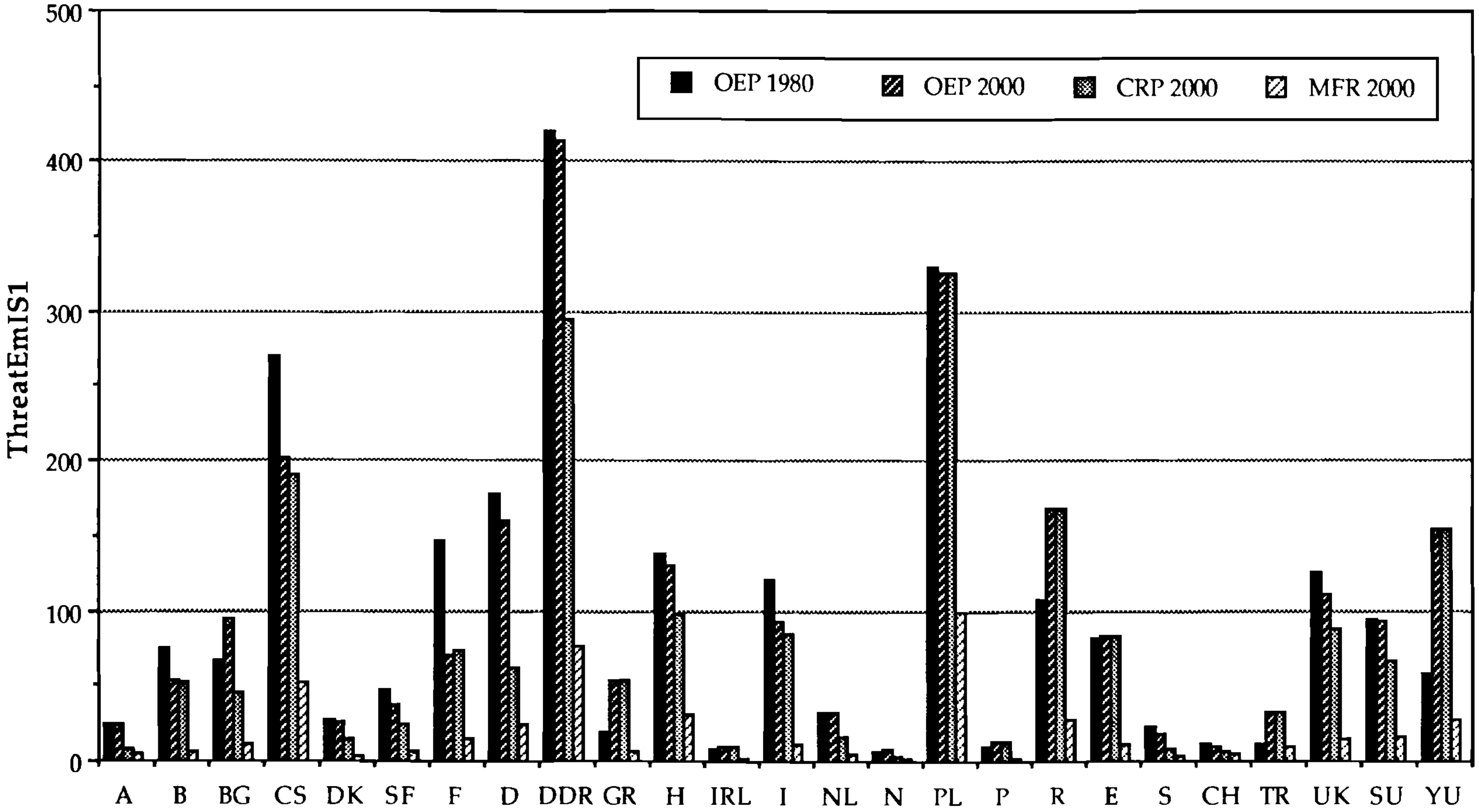


Figure 10: Threat from Exported Emissions - ThreatEmIS2
(adjusted for population size in 1980)