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The Effect of Global Environmental Regimes: A Measurement Concept

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ABSTRACT. The article outlines a method to measure the effect which international regimes have on solving global environmental problems such as global climate change. By using political–economic cost/benefit analysis, a no-regime counterfactual and a collective optimum (lower and upper bounds) are derived. By comparing the actual performance of a regime to these bounds, a simple coefficient of regime effectiveness can be computed. After theoretically deriving the various bounds, the authors discuss the determining factors and provide guidance on how such a research agenda could be pursued empirically. The authors conclude with suggestions to further refine the measurement concept and its merit for public policy.

Introduction

As Michael Zürn eloquently concludes in a major review of the progress of research on international environmental policy, regime effectiveness has become a "driving force in the analysis of international relations" (Zürn, 1998: 649). Martin and Simmons (1998: 742–757) more generally assert that the study of international regime effects serves as a major field of current research in international relations. Much of this research now originates in the environmental field.

In a first phase, major efforts concentrated on the conditions that give rise to international regimes (Gehring, 1994; Hasenclever et al., 1996; Keohane, 1984; Keohane and Nye, 1989; Rittberger, 1995; Young, 1989a,b; Young and Osherenko, 1993). In the second phase of research, attention shifted toward regime implementation and compliance (Chayes and Chayes, 1991, 1993; Hanf and Underdal, forthcoming; Victor et al., 1998; Weiss and Jacobson, 1998). The ultimate question, however, remains if the international regimes formed actually matter (Haas, 1989; Haas et al., 1993; Underdal,

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1997; Young, forthcoming). While prior work has led to a practical measure for the evaluation of international regimes which regulate *transboundary* environmental problems (Helm and Sprinz, 1999), this article shows that an equivalent measurement instrument can be developed for environmental problems that are *global* in scope.

After presenting the general measurement concept for regime effectiveness and its explicit form for global environmental problems, the basic solution and its implications are discussed. Subsequently, the requirements for empirical research on the effectiveness of global environmental agreements are illustrated by way of reference to the case of global climate change. In the concluding section, the findings are summarized and suggestions are made for extending this approach to a broader range of global environmental problems.

Determining International Regime Effectiveness

The General Concept

The conceptualization of "regime effectiveness" varies considerably across the literature. In an ideal world, however, all of these conceptualizations should honor the following minimal requirements:

(1) focused, conceptual definition;
(2) ease of operational measurement;
(3) comparability across time and issue areas; and
(4) the ability for aggregate (regime-wide) performance measures as well as disaggregated (country-level) measures to be taken in a nested way.

While such requirements may be intuitively appealing, there is considerable divergence on even the first aspect, namely the definition of regime effectiveness.

In *Institutions for the Earth*, Keohane et al. (1993:7) respond to this challenge by asking the question: "Is the quality of the environment or resource better because of the institution?" Due to a lack of data, they suggest a "focus on observable political effects of institutions rather than directly on environmental impact." According to Jacobeit (1998), much research has focused on variables of political behavior, spanning either the economic–political domain (Keohane and Levy, 1996), the legal–political domain (Victor et al., 1998), the comparative dimension—the latter enhanced by the linkages between domestic and international environmental policy (Schreurs and Economy, 1997)—or emphasizing the processes of international regimes, especially feedback loops over time (Oberthür, 1997).

The broadest conceptualization of regime effectiveness has been offered by Young (forthcoming), who augments the problem-solving aspects of regime effectiveness with (1) the legal approach (compliance), (2) the economic approach (economic efficiency), (3) the inclusion of normative principles such as "fairness or justice, stewardship, participation, and so on", and (4) the political approach, geared toward initiating actions which may ultimately lead to the achievement of the far-reaching goals espoused by international framework conventions (see Young and Levy, forthcoming: 5–6). As a result of such comprehensive approaches, constructing comparable measures of regime effectiveness may be extremely demanding.[1]

Two approaches of the *problem-solving* tradition have operationalized the concept in numerical form: Underdal (1997) and Helm and Sprinz (1999). The logic pursued by both teams follows the conceptual steps suggested by Underdal: (1) What precisely constitutes *the object* to be evaluated? (2) Against which *standard* is the object to be evaluated? (3) *How* do we operationally go about comparing the object to our standard; in other words, what kind of measurement operations do we perform in order to attribute a certain score of effectiveness to a certain object (regime)? (Underdal, 1992: 228–229) (italics in original).

In answering these questions, Underdal (1997) develops ordinal scales for improvement over a (no-regime) counterfactual for behavioral and technical optima. Helm and Sprinz (1998) go one step further and specify the three important aspects raised by Underdal, first, specifying what is to be explained, for example, regime effectiveness in terms of (environmental) problem-solving; second, determining the lower and upper bounds into which such regime performance may fall; and third, suggesting a practical measure.

To this end, two important aspects should be distinguished: problem-solving and the principal instrument used to accomplish it. For example, in environmental regulation, the ultimate goal is to reduce environmental vulnerability, whereas the principal instruments chosen include mitigation (emission reductions of greenhouse gases[2]) and adaptation (increasing the resilience of regional ecosystems). Thus, the instrument used has to contribute to problem-solving. If more than one dimension of problem-solving exists, it is often prudent to consider incorporating more than one instrument of policy intervention and subsequent use of indices to measure the combined effects on problem-solving.

The degree of problem-solving will fall between lower and upper bounds. The lower bound is represented by the "no-regime" counterfactual[3]: none of the instruments used to solve the environmental problem can be ascribed to the *international regime*. In contrast, the actors involved in an international regime can overcome the lower bound (where they do not cooperate) by cooperating to maximize their joint welfare. The reason is that in the case of transboundary or global environmental problems, problem-solving activities undertaken by one country also profit other countries. In economic theory, it can be shown that if the marginal collective costs of using the policy instrument (in this case, emissions reductions) equate to the collective benefits, a "collective optimum" has been found (Tietenberg, 1992). Alternatives for such a collective optimum could also be derived by way of environmental thresholds such as the absence of exceeding critical loads in the case of transboundary acidification.[4]

By assessing the positions of actual policy relative to the no-regime counterfactual and the collective optimum, we arrive at a simple coefficient of regime effectiveness, which falls strictly into the interval [0, 1] (see Helm and Sprinz, 1999). This procedure can be applied to each country as well as to the aggregate of all countries, resulting in nested effectiveness scores on both levels! The general solution shows a range of advantages: It is not limited to a particular policy instrument; it can be used by researchers of various methodological orientations (more qualitatively or more formally oriented researchers); and it is easy to interpret in the applied context by policy-makers. Furthermore, it can be applied to different types of international environmental problems, such as transboundary and global environmental problems (ibid.). Given its generic reasoning, it may also hold some promise of being extended to other substantive domains of international political economy.

The Concept of Global Environmental Problems

Global environmental problems have become particularly prominent in the wake of the discovery of the thinning of the stratospheric ozone layer, which ultimately led to the conclusion of the 1986 Montreal Protocol and additional regulations to reduce and eliminate emissions of ozone-depleting substances (Sprinz and Vaahtoranta, 1994). Subsequently the problems posed by global climate change (GCC) have dominated the global environmental agenda, but other issues, such as biodiversity and desertification, are also global environmental problems.

In general, global environmental change (GEC) problems are characterized by the following mechanism: emissions around the globe (such as greenhouse gases) are aggregated and chemically transformed by an environmental medium (the atmosphere), but the effects of this global mixing vary *by region* (see Sprinz, 1997). For example, while global climate change is expected to lead to an increase in the global mean temperature, it is more important to learn what the average temperature increase (or decrease) will be for a smaller region, the state of Michigan, or Bavaria, for example.

While the effects may be region-specific, the magnitude of the causes is clearly dependent on the policies of all countries. We assume that all countries wish to maximize their net benefits even in the context of global pollution problems, and will compare the benefits and costs of their actions and undertake choices based on optimal calculus (Tietenberg, 1992; Nordhaus and Yang, 1996). While engineering studies can often define internationally comparable cost functions for controlling emissions, this is rarely the case for damage cost functions. Therefore, we will modify the economic damage functions (see Pastor and Wise, 1994) to derive lower and upper bounds of optimality.

We assume that the abatement costs $C_i(E_i)$ for country i are a convex, monotonously decreasing and continuously differentiable function of national emissions E_i. Similarly, the damage costs are a convex, monotonously increasing function, which will be corrected for two aspects. First, a regional environment shows some resilience to adverse changes, represented by an environmental threshold T_i. As a consequence, (positive) damage costs occur only to the degree to which environmental thresholds are exceeded. Second, these corrected economic damage costs are combined with a factor of political intervention, p_i, as political actors, such as environmental non-governmental organizations, may influence the perception of damages.

In order to derive the lower bound or no-regime counterfactual, country i is assumed to minimize its total costs, which are the sum of abatement costs and political damage costs with respect to the instrument of intervention, namely emissions (E_i):

$$\min_{E_i} [\text{abatement costs} + \text{political coefficient} * (\text{damages} - \text{env. threshold})] \quad (1)$$

Environmental damages are dependent on worldwide emissions $\sum_k E_k$, and their regional impact factor g_i. The latter is assumed to be dependent on the magnitude of worldwide emissions. Since countries focus on their own abatement and damage costs in the no-regime situations, equation (1) can be rewritten as follows (if the environmental damages exceed the level of the threshold):

$$\min_{E_i} [C_i(E_i) + p_i \, (g_i \sum_k \mathrm{E}_k - T_i)] \text{ with } p_i \geq 0, g_i \geq 0, i,k = 1, \ldots, \mathrm{n}, \text{ and} \quad (2)$$

$$\sum_i E_i = \sum_k E_k.$$

Taking the first derivative of equation (2) with respect fo E_i yields the following optimum:

$$\frac{\partial C_i}{\partial E_i} + p_i \left(\frac{\partial g_i}{\partial E_i} \sum_k E_k + g_i \right) = 0$$

$$\Leftrightarrow - \frac{\partial C_i}{\partial \mathrm{E_i}} = p_i \left(\frac{\partial g_i}{\partial \mathrm{E_i}} \sum_k E_k + g_i \right) = p_i \frac{\partial \mathrm{g_i}}{\partial \mathrm{E_i}} \sum_k E_k + p_i g_i \qquad (3)$$

As the second derivative

$$\frac{\partial^2 C_i}{\partial^2 E_i} + p_i \left(\frac{\partial^2 g_i}{\partial^2 E_i} \sum_k E_k + 2 \frac{\partial g_i}{\partial E_i} \right)$$

is positive by the assumption of convexity, the solution is a minimum.

In contrast to the no-regime counterfactual (lower bound), in the collective optimum (upper bound) each country i takes into account not only the damage to itself, but also that to all other countries. Accordingly, the objective is to minimize the sum of abatement and damage costs, each aggregated across countries j:

$$\min_{E_i} \left[\sum_j C_j(E_j) + \sum_j \left(p_j \left(g_j \sum_k E_k - T_j \right) \right) \right]. \qquad (4)$$

with $p_i \geq 0, p_j \geq 0, g_i \geq 0, g_j \geq 0, i,j,k = 1, ..., \mathrm{n}$, and

$$\sum_i E_i = \sum_j E_j = \sum_k E_k.$$

In view of this minimization of global costs, the first derivative of equation (4) with respect to the optimal emission level E_i is:

$$\frac{\partial C_i}{\partial E_i} + \sum_j p_j \left(\frac{\partial g_j}{\partial E_i} \sum_{\mathrm{k}} E_k + g_j \right) = 0$$

$$\Leftrightarrow - \frac{\partial C_i}{\partial E_i} = \sum_j p_j \left(\frac{\partial g_j}{\partial E_i} \sum_{\mathrm{k}} E_k + g_j \right) = \sum_j p_j \left(\frac{\partial g_j}{\partial E_i} \sum_{\mathrm{j}} E_k \right) + \sum_j p_j g_j \qquad (5)$$

As the second derivative

$$\frac{\partial^2 C_i}{\partial^2 E_i} + \sum_j p_j \left(\frac{\partial^2 g_j}{\partial^2 E_i} \sum_k E_k + 2 \frac{\partial g_j}{\partial E_i} \right)$$

is again positive, equation (5) reflects a minimum.

Interpretation of Central Parameters and Solutions

The optimal solutions derived above in conjunction with information about the actual emissions of countries, permit an assessment of global environmental regimes. Before turning to the requirements for empirical research, we will briefly interpret some crucial coefficients.

Three aspects will be emphasized: (1) environmental thresholds T_i, (2) the regional effects parameter g_i, and (3) the political parameter p_i.

First, it may be surprising that the optimal policies in the no-regime counterfactual as well as in the collective optimum are not dependent on the environmental threshold T_i in a country. In fact, this is an artifact of the functional form of the objective functions: if the economic damages were squared and then multiplied by the political factor p, all derivatives would make any solution conditional on the regional environmental threshold.

Second, the magnitude of the regional effects parameter g_i is dependent on the amount of emissions across all countries $\sum_k E_k$, its magnitude changing with the amount of atmospheric concentrations of greenhouse gases in the long-term equilibrium solution. To the degree that countries may actually influence the environmental damages they face, for example $\partial g_i/\partial E_i \sum_k E_k$ in equation (3), the sign and magnitude of this effect may become critical. If it is positive, then the no-regime optimal policy calls for larger emission reductions as compared to the case when this derivative is zero. However, should the partial derivative be negative, then economic damages seem to decline in total—and countries would actually have an incentive to emit more! In practical terms, this should only hold if some countries actually benefit from larger emissions while others consider this a growing global environmental problem: areas currently too cool to grow wine might actually benefit from regional warming (assuming sufficient water supply and appropriate soils), whereas other regions around the world might lose fertile agricultural soils. The varying signs and magnitudes of $\partial g_i \backslash \partial E_i \sum_k E_k$ reflect the potential for conflict of interest among countries.

Third, the parameter p_i represents the impact of politics on economic evaluation. It is assumed in the objective functions that politics only influences the damage function, resulting in "political damages." Theoretically, it would also be possible to attach a political parameter to the abatement costs $C_i(E_i)$, however, unlike damage costs, emission costs can often be derived from engineering or technology studies. Thus, there is often much more political controversy about damages than about abatement costs.

In the optimum solution, p_i plays a central role. If it assumes the value of "one," we arrive at the *economic* solution to a global environmental change problem. Such a situation is plausible if the political debate between the various interest groups leads to a "balanced" evaluation of damages: No important national political actor is capable of outweighing others. Alternatively, the political system favors neither those who emphasize the perception of large damages, nor those who insist on taking an optimistic view of the global environmental problem.

Alternatively, p_i may take values either in the interval [0,1] or is larger than unity. In the first case, "existing" economic damages of global environmental change are systematically devalued, by a preponderance of actors who perceive the threat of economic damages to be exaggerated, by disbelief in the scientific reasoning underlying the global environmental change problem (such as the so-called "climate skeptics"), or even by political ignorance on the topic. In fact, if the political process does not attend to a problem, p_i will assume the value "zero" and emission reduction policies will be contemplated only if the abatement costs are negative. This is captured by the term "no regrets" policies. In the field of international climate policy, low p_i values seem to apply to a range of countries falling into the "Group of 77 plus China" who do not wish to agree openly to emission reductions of greenhouse gases because they prioritize economic development (Sprinz and Luterbacher, 1996; Sprinz, 1998).

In the second case, where p_i assumes values larger than unity, economic damages of global environmental change are politically magnified. For example, in prior research, it was found that countries undertake emission reduction policies in the context of the European acid rain problem even beyond the requirements for a collective optimum (Helm and Sprinz, 1999). In the context of global climate change it appears plausible that some European lead countries display a preponderance of pro-environmental groups over the political clout of those interested in very small emission reductions; lead countries such as Austria, Denmark, Germany, and the Netherlands are likely to experience p values larger than unity; at a minimum, their p_i is larger than is the case for the "Group of 77 plus China."

Requirements for Empirical Research

The measurement of the effectiveness of global environmental regimes will ultimately assist decision-makers in determining to what degree the international policies undertaken have indeed contributed to problem-solving. In the following, we undertake a preliminary exploration of some components needed for making such an assessment in the context of global climate change.

First, abatement cost functions are a key component of a political–economic cost/benefit analysis. Ultimately, abatement costs are based on technological information to a considerable degree, but wider cost categories (for example, macroeconomic effects of interventions) may also be included. With future technologies unknown, we can only make assumptions about the future of technological improvements. Furthermore, country-specific information is necessary for the specification of comparable cost functions, and positive side-effects of emissions reductions outside the immediate domain of regulation should be subtracted from the computation of national abatement costs. While there is considerable discussion about abatement cost functions (Bruce et al., 1996, chaps. 8–9), they can be utilized in an exploratory political–economic cost/benefit analysis.

Second, the emission reductions for the "no-regime" counterfactual must be determined. While a range of approaches is possible, including game-theoretic models and optimization routines, it appears most fruitful to ask a range of experts to provide independent country-specific emissions information through a structured process. Once extreme values across this range of experts are removed, the no-regime counterfactual emissions and the associated damage costs can be derived indirectly.[5]

Third, the collective optimum must be determined based on equation (5) by taking account of the effects countries have on each other. An alternative approach would focus on studies that compute the global optimum based on a simplified world-wide assessment (that is, the global emission reductions needed to achieve a specified environmental threshold in most countries of the world), and "shares" of emissions would be distributed by way of utilizing an algorithm which distributes minimum aggregated costs along the individual abatement cost functions of countries.

Fourth, such economic data would have to be modified by the political factor p_i. In prior research, a structured assessment of the major actors pushing for higher vs. those pushing for lower emissions reductions was undertaken, and their relative political weights, salience, and revealed emission reduction goals could be used to compute a weighted p_i (Helm and Sprinz, 1999). Such research should be executed by country experts with the help of standardized coding rules and intercalibration procedures.

Fifth, parameters of regional environmental impacts may be the most difficult to derive. While a major assessment of climate change impacts has been undertaken (Watson et al., 1996), it deals separately with each impact category. Since countries are normally exposed to more than one impact category, an indicator of country-level comparison has to be created. It must also be decided whether to concentrate on the most prominent damage category (such as changes in harvests, and flooding events) or if a weighted index of climate impacts should be used.

Overall, a range of problems must be solved to allow for an operationalization of the measurement instrument outlined above. Fortunately, such research could build on the advances made by prior research, especially the work by the Intergovernmental Panel on Global Climate Change (IPCC).

Agenda for Future Research

This article has outlined a concept for the measurement of the effect of global regimes on the regulation of global environmental problems. Driven by the logic of political–economic cost/benefit analysis, it systematically derives lower and upper bounds into which a country's performance should fall. In conjunction with a country's actual or anticipated performance, this allows for a non-arbitrary assessment of the effect of international regimes on solving global environmental problems.

A range of simplifying assumptions has been made to allow for the parsimonious derivation of results. Relaxation of some simplifications will be considered below—which ultimately leads to more complex and adequate solution concepts.

First, the regulation of a global environmental problem was approached in a static way: a one-period model was created when the reality would call for a dynamic concept. In particular, a dynamic representation allows for the build-up of an intergenerational problem over time rather than in a discrete event. Dynamic treatments more adequately reflect the actual problem structure: the depletion of the stratospheric ozone layer and its potential recovery later in the next century are dynamic processes. The potential threat posed by the net accumulation of greenhouse gases over time is another example. As a consequence of dynamic modeling, research will focus on emission paths, and abatement and political damage costs will become time-sensitive.

Second, the political parameter p_i may not only be time-sensitive, but it may also be dependent on the magnitude of the economic damage (such as those potentially caused by greenhouse gas concentrations), and may simultaneously provide a solution to model political pressure over time.

Third, it would be desirable if environmental thresholds entered into the calculation of the no-regime counterfactual and the collective optimum. This can be accomplished by using quadratic economic damage cost functions.

Fourth, the general measurement concept uses the instrument of intervention as the measuring tool of regime effectiveness. The concept is not only useful for the study of mitigating problems (such as focusing on emission reductions), but it could also use adaptive measures as the instrument of intervention. Such modeling would more clearly focus on the cost and benefits of enhancing the resilience of ecosystems. In particular, modeling would focus in detail on the environmental threshold T_i.

Fifth, the measurement concept should be probed for extensions to other global environmental problems for comparative assessment. This would allow for the comparison of the regulation of such events as climate change and stratospheric ozone depletion.

The research suggested in this article has a major practical merit. Policy-makers currently have no standard instrument to evaluate the performance of international regimes and the treaty-making activities in which they presently invest; studies on regime effectiveness, if conducted in a rigorous, reproducible, and explicit way, would help to decide where resources should be best allocated, namely wherever the potential gains of one unit of intervention are greatest. The preferred outcome is not complete problem-solving in a few issue domains, but investing in interventions that yield major gains. If the present research provides a modest contribution to such an end, it will have been worth the effort.

Notes

1. For a comprehensive review of current research on the effectiveness of international environmental regimes, see Sprinz (1999).
2. Jacobeit (1998: 348) and Zürn (1998: 830) find emission-based approaches to the measurement of international regime effectiveness particularly promising.
3. For counterfactual methods, see Fearon (1991) and Tetlock and Belkin (1996).
4. See Sprinz and Churkina (1998) for a method to generally derive environmental thresholds.
5. See Mäler (1990).

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