Modeling Environmental Conflict

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Detlef F. Sprinz

1 Introduction[1]

Scientific consideration of the topic of 'environment and security' is part of the renewed discussion of the concept of security towards the beginning of the third millennium. Academic research faces a dual question: Is it scientifically fruitful to expand the concept of international security, which was originally restricted to research into the causes of wars, and to what extent is the environmental dimension of security policy suitable for practical policy-making? Answering the second question ideally presupposes a fruitful discussion of the results of scientific research, although policymakers expect answers in this field from science which is just evaluating the first generation of its research programs – and many questions are *necessarily* subject to a debate about content and methodology. This paper takes up this challenge by presenting a methodological critique of some empirical-qualitative research programs that are important for politics and political science (Section 2), and briefly compares some advantages of empirical-quantitative research methods (Section 3). Subsequently, it will be shown how environmental thresholds can be conceived of as a sufficient condition for the outbreak of violent conflict and how research on environmental thresholds can be incorporated in an empirical-quantitative research design on environmental problems and the outbreak of violent conflict (Section 4).

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2 Methodological critique of some empirical-qualitative projects

Two research programs with an empirical-qualitative orientation are dominating the political and scientific discussion of the effect of environmental problems on the outbreak of armed conflicts within and between states: that of Homer-Dixon, and that of Baechler and Spillmann.[2] For reasons of brevity, the criticism of the two programs can only be outlined.

In his first concept, Homer-Dixon develops a research design that lets macro-variables (such as population pressure, economic activity, and institutions) be the cause of environmental effects – which, in turn, result in unwanted social effects and potential armed conflict (see in particular Homer-Dixon 1991:53). For special problems, such as a decline in agricultural productivity or economic activity, high-resolution cause-and-effect models of path-tracing analysis are developed, which are intended to explain the origin of conflicts due to scarcity and group identity or the conflicts originating from relative deprivation. These detailed theories are often considerably too complex for systematic tests[3], and omit major theoretical aspects. The first problem results from the testing of nonequivalent causal structures, which make the empirical comparison of results very difficult or impossible; and the second problem results, for example, from an insufficiently comprehensive concept, since political intervention (e.g. environmental policy measures or policies for restricting actual or potential violence (see Section 4)) are not included systematically in the research program – although it is true that such variables are mentioned in Homer-Dixon's general set of ideas.

This original model was revised by Homer-Dixon in view of his empirical findings (Homer-Dixon 1994). However, some theoretical aspects remain unclear: sometimes, variables appear as *causes* (in path-tracing analysis) of environmental problems ('environmental scarcity'), but on other occasions, they seem to be *measures* of environmental problems. But variables can only fulfill one of these two functions, not both at the same time. On the other hand, "social and technical ingenuity", rightly emphasized by Homer-Dixon, is unfortunately not integrated into the concept.

Although Homer-Dixon does base his work on numerous detailed case studies, his selection of cases leads to a serious methodological inference problem. Only such cases were selected that involve *both* environmental problems and the outbreak of armed conflicts (Homer-Dixon 1996). This simply does not permit causal analysis[4] of inference whether environmental problems lead to armed conflicts – since the selection criteria make precisely this (correlative) connection. Furthermore, it remains unclear which *method* of inference is chosen, especially

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[2] A comprehensive critique of the literature on the environment and armed conflict is given in Gleditsch (1998).

[3] Gleditsch (1998) speaks of "untestable models".

[4] On the preconditions for causal analysis links, see Cook and Campbell (1979: 18) int. al.

since the uniqueness of each case is emphasized (Homer-Dixon and Percival 1996: 3). Overall, Homer-Dixon's research strategy shows a number of validity problems (see Cook and Campbell 1979: Chapter 2), which considerably restrict the use of the results for policymaking.

In addition to Homer-Dixon, Baechler and Spillmann have undertaken a large-scale study of the link between environmental problems and armed conflict as part of the Environment and Conflicts Project (ENCOP: Baechler et al. 1996; Baechler and Spillmann 1996a; Baechler and Spillmann 1996b). Unlike Homer-Dixon's explicit theoretical work, their project lacks an *ex ante* formulation of research hypotheses. On the methodological side, it remains unclear which factors must systematically accompany environmental degradation in order to account for the outbreak of armed conflict. Furthermore, exceeding environment threshold values (see Section 4) is occasionally mentioned as a precondition for armed conflicts, but this important idea is not taken up systematically and operationalized throughout the case studies. As with Homer-Dixon, a method of inference which systematically evaluates the impact of causes (e.g. environmental degradation) on effects (armed conflict) is lacking.

The research projects headed by Homer-Dixon as well as Baechler and Spillmann succeeded in directing the attention of political decision-makers on both sides of the Atlantic to the important research question of whether environmental problems lead to armed conflicts. However, due to the methodological weaknesses of the two programs, we unfortunately still do not know whether this correlation exists to a substantial degree, or not. Thus, researchers find themselves in the not uncommon, but less than desirable situation that neither the hypothesis that environmental problems lead to wars, nor the alternative hypothesis (environmental problems do not lead to armed conflict) can be refuted. Because of theoretical and methodological weaknesses, the case history remains incomplete, the diagnosis of the (non-)existence of a general cause-and-effect relationship between environmental problems and armed conflict cannot yet be made, and remedies in the form of recommendations for political action seem quite premature in view of the difficulties encountered in the previous steps.

But these research shortcomings are by no means unusual for such a new field of research as environment and security. Almost every field of research refines its theory and methods over the course of time, as part of a fruitful scientific discourse. The suggestions in the two sections to follow are intended to contribute to the advancement of the field.

3 Advantages of empirical-quantitative research approaches

Empirical-qualitative and empirical-quantitative research approaches are not necessarily derived from differing research strategies – the stages of research are largely similar in both cases (see Mitchell 1998; Sprinz 1998). However, the research design and execution of empirical-quantitative research programs are usually more rigorous.

In an empirical-quantitative research design, researchers must first define the phenomenon to be explained (dependent variables), in order to delimit the object of research (see Table 1). Next, it is advisable to develop a specification of hypotheses, which give the research design a theoretical framework, incorporate previous research results, and permit testing of alternative or complementary research hypotheses. Thus one's own research project is integrated in the broader research enterprise of the policy area under consideration. These first two stages also determine which variables are to be newly collected, or are to be derived from existing sources of data. The scaling of both dependent and independent variables is important, since this affects the selection of the statistical method for analyzing the co-variation of dependent and independent variables, as well as the extent of variation of each variable. In a fourth stage, the statistical method is selected, and the results are interpreted – with the validity of the results (fifth stage)[5] being decisively influenced by the previous decisions (the second and third stages, in particular). Finally, recommendations for further research, as well as recommendations for public policy (where applicable), are often provided.

Table 1: Research stages within an empirical-quantitative research design

Research stages
1. Selection of the phenomenon to be explained
2. Development of the theory and specification of hypotheses
3. Determination of the data sources and scaling of variables
4. Selection of the statistical method and interpretation of the results
5. Checking the validity of the results
6. Consequences for future research, and possible recommendations for public policy

Source: See Dreier 1997; Schnell et al. 1995

Empirical-quantitative research often has advantages over qualitative research, and can make a major contribution to scientific research and public policy based

5 See Cook and Campbell 1979.

on it, especially in the field of 'environment and security' (see Table 2). A clear specification of the theoretical model before performing research permits conceptual synthesis, which has not yet been achieved in qualitative research in the field of environment and security. In addition, the collection of data in quantitative research compels the researcher to specify the level of analysis, i.e. the unit of data collection within a geographical area (e.g. 10 x 10 km^2) and specified period (see Gleditsch 1998). These specifications shape the interpretation of the results, and show explicitly how theoretical concepts are (often incompletely) operationalized. Furthermore, the choice of the method of inference allows the results to be obtained on the basis of a documented algorithm (rather than the subjective impression of a researcher) – they can then be tested by means of replication (including other methods of inference) and sensitivity analyses to see how well they stand up. In addition, empirical-quantitative methods can often be illustrated with modern methods of static (e.g. tables and diagrams) and dynamic (e.g. video representation of the dynamics) visualization. The choice of empirical-quantitative methods does not solve all research problems automatically, but it makes them apparent, permits independent replication, and promotes a transparency in research that is often lacking in empirical-qualitative research projects.

Table 2: Selected advantages of empirical-quantitative research

Advantages
Clear specification of the theoretical model (*ex ante*)
Specification of the level of analysis, unit of analysis, temporal and geographical scale
Explicit operationalization of theoretical concepts
Specification of method of inference; replication and sensitivity analysis
Visualization of data and findings

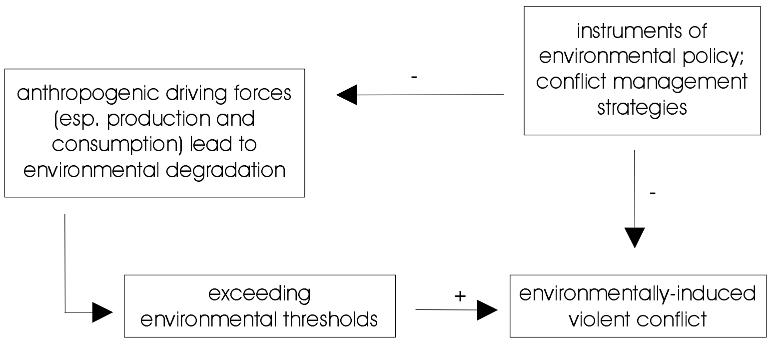
Source: Sprinz forthcoming (revised)

In the following section, two aspects of an empirical-quantitative research design for explaining environment-induced armed conflict are discussed, in particular the specification of a simple general model (research stage 2), and requirements upon data collection (research stage 3).

4 The study of environmental thresholds

This section suggests an empirical-quantitative research program on environment and security. This includes crucial aspects of the overall relationship among variables and the derivation of environmental thresholds as a sufficient condition for the systematic diagnosis of environmentally-induced armed conflict.
Environmental problems are normally the result of anthropogenic activities (such as the production and consumption of goods, population growth, etc.) that damage the environment. But not every impairment of the environment is associated with severe environmental degradation that may increase the probability of armed conflicts. Rather, when an environmental threshold (see below for the definition) is exceeded, this may become a precondition for *environmentally*-induced violent conflict. Only if this environmental threshold is exceeded (or several are exceeded synergetically) can environmentally-induced armed conflict be diagnosed at all. Thus it is the specification of a sufficient variable (environmental thresholds) which allows us to limit ourselves to a subset of violent conflict (see Fig. 1).[6]

Figure 1: The relationship between environmental threshold values, armed conflict, and political intervention



This delimitation has two important implications for research. First, the scope can be narrowed considerably, especially with regard to the independent variables, since not every cause of armed conflict has an environmental component, or is causally linked to environmental problems. As mentioned above, exceeding environmental thresholds does not necessarily always lead to an outbreak of armed conflict, since governmental and non-governmental actors can employ the instruments of environmental policy as well as of conflict management. Second, this leads to a systematic expansion of the chain of cause and effect by including

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6 If environmental degradation is one of many necessary conditions for the outbreak of armed conflict, studies of 'environment and security' should be included in the general research on the causes of war.

important possibilities for intervention: one the one hand, successful employment of the instruments of environmental policy (see Sprinz 1997) can lead to a modification of the anthropogenic forces of environmental degradation over time, resulting in the impact *dropping below* the environmental threshold; on the other hand, strategies of conflict management may reduce the probability of armed conflict even if environmental thresholds have been exceeded.[7] The latter seems probable under legitimate legal and social systems in democracies or if generous compensation is provided for environmental damages.

Thus, the diagnosis of whether environmental thresholds have been exceeded is central to research on environment and security. Only then can we diagnose *environment*-induced armed conflict. Otherwise, environmental problems are secondary causes – and should then be incorporated as a minor aspect in the general analysis of the causes of war. The answer to the question of whether exceeding environmental threshold values is a sufficient condition for the outbreak of armed conflicts within or between states is also of great importance for public policy, since it assists in setting political priorities.

Environmental thresholds may be described as states in which the functioning of natural systems changes fundamentally (Sprinz and Churkina 1998). For example, plants wilt at pressure values beyond minus 1.5 megapascals, since they can then no longer extract water from the soil. Determining environmental threshold values has a long tradition in the natural sciences (e.g. Parry et al. 1996) and in the field of medical research (e.g. Rosenthal et al. 1992), but it has not been much used in the social sciences. The following steps are routinely used in the USA for estimating cancer hazards in the context of medical research:

- determination whether a cause leads to an effect at all, with the help of the 'maximum tolerable dose',
- determination of a 'dose-effect function', determined by varying the dose,[8]
- determination of the magnitude of the dose actually occurring (actual exposure), and
- risk evaluation, a part of which is to transfer the results from the two previous steps into a common metric (e.g. currency units) (Rosenthal et al. 1992.).

The central relationship of the dose-effect function is illustrated in linear form in Fig. 2. The dose occurs as a cause (e.g. emission of air pollutants) that leads to unwanted effects (e.g. forest die-back). Dose-effect function A shows a constant relation between dose and response, in contrast to Function B, which deviates from Function A from the discontinuity point (threshold value) on. From then on, Function B has a considerably sharper rise than Function A for higher values of the dose (see Fig. 2).

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7 With respect to the critique presented in Section 2, this research design is both more narrowly focused and more comprehensive due to the inclusion of a response module.

8 In the field of human medical research, a safety factor of 1:100 or 1:1,000 is usually incorporated, and the dose-response function is extrapolated into this range (Rosenthal et al. 1992).

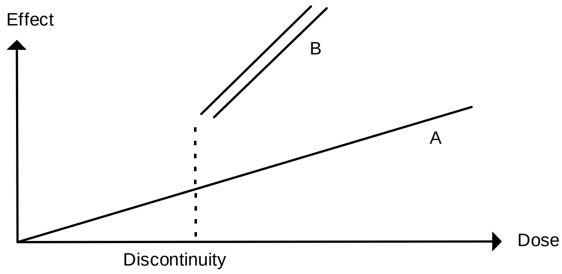

Figure 2: Threshold values and dose-effect relationships

The determination of environmental threshold values can be done in three different ways. One obvious approach is to look for the value of the dose at which any effect occurs at all (Rosenthal et al. 1992). In the case of Fig. 2, this would be reached at a value of the dose infinitesimally larger than zero. However, small effects are often (though not always) accepted in research and political practice, since absolute safeguarding of the functioning of every ecosystem or of people would be unduly expensive, and other political goals could no longer be pursued for lack of available resources. Secondly, they can be defined as not exceeding a socially 'acceptable' level of impact, such as if forests go from damage level 1 to 2 on a four-point scale (UNECE/Executive Body for the Convention on Long-Range Transboundary Air Pollution/Working Group on Effects 1991). A third way consists of systematic indication of distinct discontinuities of the dose-effect function, such as can be seen in the deviation of Function B from A from the discontinuity point on (see Fig. 2).
For research in the field of environment and security, the latter two approaches to environmental threshold values seem the most promising, since they often realistically allow a minimal dose of harmful substances. The scaling of eco-systems (e.g. into categories of vegetation zones) often models the effect side of the second research approach – in global environmental change research, corresponding transitions from one level of a classification to another are then either forecast or explained in retrospect as the result of environmental changes (e.g. changes in important regional climate parameters). On the basis of the above definition of environmental threshold values, the third type of study seems the most interesting, since it takes the predicted or observable discontinuities of the dose-effect relationship directly as its subject. The latter approach also plays a major role in research on 'surprises' (see Glantz 1997; Schneider and Turner II 1995) in the context of global environmental research, since discontinuities are ultimately surprises (about effects) in the broader sense.
Environmental thresholds are not necessarily scaled one-dimensionally, but comprise at least a number of important dimensions, which are outlined for the case of 'acid rain' in Table 3. Environmental threshold values may be absolute and abrupt (see Fig. 2), or take the form of intervals, include a temporal dimension (static or dynamic), occur as a single discontinuity or several times in the curve of

the dose-effect function, and differ in their extent or their degree of reversibility by environmental policy measures. Furthermore, knowledge of each of these four aspects plays an important role, since different environmental threshold values have often evoked varyingly intensive research interest.

Table 3: Dimensions of environmental threshold values

Dimension	Example: 'acid rain'
Type (absolute, abrupt, intervals)	absolute and abrupt
Time (static vs. dynamic)	dynamic and long-term
Number (one vs. more than one)	one threshold value per pollutant (for a given level of deposition of other pollutants)
Degree of reversibility of overshoot (at low, medium, high costs; irreversible)	reversible (depending on the degree of optimization of international emission-reduction strategies)
Extent of knowledge about the above dimensions	high, especially about sulfur and nitrogen oxides

Source: Sprinz and Churkina 1997 (slightly revised)

The determination of the existence of environmental threshold values can be approached in a variety of ways. However, regardless of the way chosen, the geographical and temporal dimension of the dose-effect relationship considered should be specified.
In a *mathematically* abstract form, discontinuities can be expressed in the static case as

$$f(x_1) - f(x_2) > \varepsilon \quad \text{or} \quad df(x)/dx > \varepsilon$$

or in the dynamic case as

$$f(x_{t=2}) - f(x_{t=1}) > \varepsilon \quad \text{or} \quad df(t)/dt > \varepsilon,$$

i.e. the function change exceeds a specified level ε. Thus the non-arbitrary definition of ε becomes an important criterion for the diagnosis of thresholds, in particular their nature, temporal dimension, and number.[9]
Adherents of statistical methods may take the *heteroscedasticity* (non-constant error variance) of linear regressions of dose-effect relationships as a clue to the possible existence of threshold values, since a linear regression causes constant error variances in the case of a linear functional link, while discontinuities cause a sudden increase of the error variance from the observed to the estimated function

9 For a more extensive discussion of discontinuities, differentiability and methods to empirically diagnose environmental thresholds, see Sprinz and Churkina 1998.

in their vicinity.[10] This method is potentially particularly suitable for routine analysis of large quantities of data; however, a minimum of *heteroscedasticity* must be specified as a criterion in order to restrict the number of meaningful threshold values.

As already discussed above, the transition between *stages in a classification* scheme on the effects side is also suitable as a criterion for determining the existence of thresholds. This method relies on the validity and reliability of the underlying measurement scale. Such scales are often relatively easy to interpret, and the factors which account for a change in the classification level are known. This latter point in turn eases the search for causal variables.

From the point of view of environmental policy, the decisive question is whether exceeding environmental thresholds is reversible. This problem has both an *ex post* and an *ex ante* dimension. In the *ex post* case, the question is whether an overshoot of an environmental threshold that has already occurred can be reversed – and if so, at what costs. In the *ex ante* case, it is the anticipation of the irreversibility of a possible overshoot of a threshold value (for example, in the case of pronounced global and regional climatic changes) that induces qualified political interventions. In both cases, the economic costs (relative to total economic activity) of reducing the dose levels back below the threshold value plays a decisive role, and thus partly determines the likelihood of the political intervention and its extent (Sprinz and Vaahtoranta 1994). In the case of technically 'impossible' reversibility, it is anticipation before environmental thresholds are reached that is of crucial importance.

In the context of determining environmentally-induced conflicts, environmental threshold values play a decisive role, since exceeding them is the sufficient condition for *environmentally*-induced armed conflicts. In this section, several empirical-quantitative approaches to determining such environmental threshold values have been shown, whose methodology can be traced explicitly, and which can be criticized systematically. At all events, the suggested approaches prevent findings about the effect of environmental hazards on armed conflicts being specific to a researcher, and therefore idiosyncratic; this also assists the derivation of conclusions for public policy.

5 Prospects: the contribution of empirical-quantitative research

Empirical-qualitative research on the environment and security has succeeded in pushing this extremely important topic into the political limelight. Thus a potential problem has become the subject of political discussion before major dangers have occurred. Unfortunately, empirical-qualitative research to date has not succeeded

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[10] This method deliberately uses linear regression methods for estimating the non-linear behavior of a function. In this exceptional case, it is the violation of linear regression assumptions that is meant to serve the diagnosis of threshold values.

in establishing whether there is a general relationship between environmental hazards and armed conflict. In this respect, politics is left in a knowledge vacuum: it cannot be demonstrated that this general relationship exists, nor that the opposite is true.

The empirical-quantitative approach proposed here concentrates on studying environmental threshold values as a sufficient condition for the outbreak of armed conflict. This would be achieved if environmental thresholds are exceeded. Otherwise, the environmental component in the causation of violent conflict is likely to be of secondary interest. Environmental thresholds can be characterized as part of an empirical-quantitative research program, utilizing several dimensions. In particular, various mathematical abstract, statistical, classificatory and economic approaches to determining environmental thresholds have been put forward. If the opportunities for environmental policy intervention and for conflict management are included, a simultaneous test of the connection between environmental degradation, violent conflict, and possible political interventions can be undertaken (see Fig. 1). We could learn why armed conflict does *not* occur in cases where, for example, environmental thresholds are exceeded, no environmental policy response is launched, but vigorous conflict management is observed. In the framework of the research design described above (see Fig. 2), findings would become possible that not only enlarge research perspectives, but also better inform public policy.

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