ENVIRONMENTAL ECONOMICS

False Alarm over Environmental False Alarms

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We live in an uncertain world, in which action and prudence must be continually juggled. Caution can be costly, but indifference to serious risks can be disastrous. In all aspects of life, we weigh risks and benefits, invoking measures to insure against events that threaten what is most important to us, while gambling with those that can be tolerated. In matters of our environment, science has the responsibility to inform these decisions, and society must find ways to identify the appropriate level of circumspection. By any calculation, we must protect ourselves against a wide variety of events that individually have low probabilities of occurrence, and still feel good when they have not occurred. We must rely on environmental science to alert us to an even wider set of possible disasters, many of very low probability, so that we as citizens can decide which cause us most worry, and which mandate action.

The unavoidable result of this prescription is that many warnings of environmental scientists will prove to have been unfounded, and others will have led to actions that prevented or mitigated the predicted dire consequences. Thus many predictions of possible environmental degradation will not come to pass, in some cases simply because those predictions were made and heeded. There will then always be critics who will trumpet the failures as evidence that we should never have paid attention to those who urged caution, and that we should hence similarly dismiss future warnings. It is by now a familiar tune. *The Skeptical Environmentalist* by Bjørn Lomborg (*1*)—officially discredited by the Danish Committees on Scientific Dishonesty

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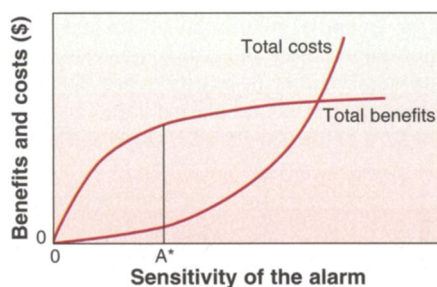
Net benefits of response to true alarms and costs of response to false alarms. At the optimum A*, the slope of the top curve (marginal benefits) equals the slope of the bottom curve (marginal costs).

(www.forsk.dk/eng/index.htm)—is the most recent of a long list of such efforts.

Nonetheless, environmental scientists need to confront an important issue, highlighted by these skeptics, that accompanies the dual role of the environmental sciences in society. Funding, research priorities, and publication standards reflect both the need to advance our fundamental understanding of the Earth's ecosystems and a responsibility to sound the alarm when a possible environmental hazard is detected. Evidentiary standards in the basic sciences are based solely on what most effectively enhances learning, whereas evidentiary standards of an environmental alarm system must balance the benefits of early detection with the costs of alarms based on an early state of knowledge (*2*).

What is the optimal level of sensitivity for society's environmental alarm? How many signals should the environmental community send to policy-makers, realizing that some (or many?) of them will turn out to be wrong? Is it true that environmental scientists are responsible for a litany of false predictions, as claimed by Lomborg and others, or is the balance between false alarms and correct ones about right, or even too conservative?

The classification of environmental alarms as either true or false obviously is too simple. Identified problems may be real, but overstated or understated, and alarms by consensus groups, such as the Intergovernmental Panel on Climate Change

(IPCC), carry more weight than those of single scientists. When a critic such as Lomborg says that the environmental community issues too many false alarms, he or she is actually saying that a reduction in the sensitivity of the environmental alarm would decrease the current regulatory costs more than it would decrease benefits. Thus, the claim of too many false alarms is a claim about the slopes of the curves relating benefits and costs to alarm sensitivity, which are called marginal costs and benefits in economics. A claim of too many false alarms thus implies that marginal costs are greater than the marginal benefits.

The structure of the cost-benefit problem is shown in the figure (left). By sensitivity (the abscissa), we mean the probability that an alarm would be sounded and acted upon in response to some reference hazard. Sensitivity thus integrates the efficiency of the environmental sciences in detecting and understanding hazards, the evidentiary standards that cause environmental scientists to issue warnings, and the societal thresholds for regulatory action when given a warning.

With this definition of sensitivity, the curves for the costs and benefits are probably nondecreasing functions. The optimal sensitivity of the alarm system occurs when the marginal benefits of alarms equals their marginal costs [A* in the figure (left)]. There is no formal mathematical reason why the system should have an internal optimum, and the formula for the optimal sensitivity is not of much practical use because we cannot obtain precise quantitative estimates of the cost and benefit curves. However, we can obtain some quantitative information that establishes a lower bound for current benefits of response to environmental alarms, and at least some information about the magnitude of the marginal benefits.

Evidence is overwhelming that humans have had enormously costly effects on the environment. Lomborg himself estimates air pollution deaths in the United States at more than 130,000 annually and over 3 million world wide, and deaths averted by the control of chlorofluorocarbons (CFCs) at more than 300,000 (*2*). Thus, even contrarian estimates of the benefits of environmental action indicate that these may be huge. Still, it is more difficult than one would think to show that this implies large benefits of responding to environmental alarms. Where successful mitigation has not yet taken place, such as with global

warming, realized benefits remain small because of our failure to act. In cases with apparently successful mitigation, the question is inevitably raised "What would the world have looked like in the absence of mitigation?" When faced with well-documented hazards and apparently successful mitigation, Lomborg and others have downplayed the role of environmental action and have argued instead that income and technology drive most improvements in environmental quality. Although economic and technical changes unrelated to environmental regulation are undeniably important in some cases, such arguments are easily dismissed in others, such as the bald eagle's recovery from the effects of DDT or the current decrease of CFCs in the stratosphere.

A popular characterization of the relation between per capita wealth and pollution is the so-called environmental Kuznets curve (3–5), which is shaped like an inverted U (see figure, right). The decreasing portion of the curve may be induced by purely technological factors, a shift in the manufacture of dirty products from more to less developed nations, or increased demand for environmental regulation in developed countries (3, 6–8). Where all of these factors may be operating at once, estimation of the benefits of environmental action is inevitably quantitative and contentious. For example, in the critical case of air pollution, emissions of several pollutants in the United States were decreasing before the Clean Air Act of 1970 (8, 9). Even so, regression analyses that relate emissions to government regulations, income, measures of environmental action, and other possible driving forces conclude that regulations played a dominant role in improving air quality. The U.S. Environmental Protection Agency (EPA) (10) estimated the net human health benefits (benefits minus costs) of the Clean Air Act at $5.6 to $49.4 trillion for a 20-year period (with a best estimate of $22.2 trillion in net benefits). In a critique of the Environmental Protection Agency study, Gallet et al. (8) also estimated large net benefits and showed that the Kuznets curve for U.S. air pollution shifted down because of the Clean Air Act. Other studies affirm the role of environmental action and attitudes in achieving the reductions (6, 11). In addition, we found that states in the United States with proportionally high membership in "green" organizations had lower Kuznets curves for air pollutants than states with lower membership rates. Similarly, nations with a high score on an index of civil liberties had lower Kuznets curves than nations with low civil liberties, probably because of public lobbying for environmental action in countries with more civil liberties (see supporting online material). These examples strongly suggest that air pollution is not simply a matter of income. In comparing states or

nations with the same level of wealth, those with more environmentalism, or greater capacity for public choice, have lower air pollution. Public choice (as a manifestation of civil liberties) of course involves much more than environmentalism, making the observed relation especially tantalizing.

The balance of the evidence indicates that we are receiving substantial benefits from our response to environmental alarms. These benefits range from aesthetic (such as our joy at the bald eagle's recovery) to the saving of millions of lives (for example, regulation of air and water pollutants). Still, the critical quantity determining whether or not there are too many false environmental alarms is the marginal benefit of the alarms—the slope of the ben-
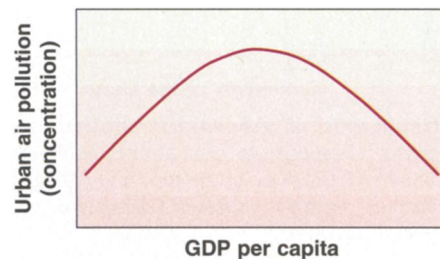
An example of an environmental Kuznets curve.

efits curve—not the absolute benefit. History tells us that most of the known anthropogenic hazards had already caused considerable harm by the time their adverse effects were even understood, let alone regulated; therefore, we argue that humans have typically lived on the steep portion of the benefits curve, rather than the asymptote. Problems of detecting warning signals and overcoming vested interests inevitably lead to delay in regulation, often incurring damages that could have been prevented with higher sensitivity. Small particulates ($PM_{2.5}$) are the most dangerous air pollutants in the United States, and these were not even regulated until 1997 because epidemiological studies showing effects at unexpectedly low concentrations were not reported until 1989–1996 (12).

Because marginal benefits are evidently so large, we argue that they dwarf the highly uncertain marginal costs in most cases. Thus, our environmental alarm is currently too conservative, not too liberal. Consider a change in the sensitivity of the environmental alarm large enough to allow, on average, one of the major million-life hazards to pass undetected. To be beneficial, such a change would have to reduce the cost of inappropriate regulations even more than the net value of the lives lost. We view this as extremely unlikely, given that the value of a single "statistical life" is usually estimated

in the low millions ($3 to $6 million currently in the United States) and that total expenditures on environmental protection in OECD (Organisation for Economic Co-operation and Development) countries are generally estimated at 1 to 2% of gross domestic product, with the United States at 1.6% (13–15). Also, new discoveries first receive considerable scientific scrutiny, and most false alarms are discarded before they engender serious costs. Furthermore, the costs of mitigation often are far less than initially projected because of induced technical change; delaying mitigation can, therefore, increase costs. Environmental policy and science are dynamic partners, and delays in addressing problems tip the balance even more in favor of early warnings and action than the static cost-benefit analysis would suggest (16).

The optimal solution of a cost-benefit analysis always leaves some members of a heterogeneous population bearing a disproportionate fraction of the costs and others enjoying a disproportionate fraction of the benefits. Thus, there will always be a robust market of special interests to popularize books like *The Skeptical Environmentalist*. Were such complaints not heard, we would be erring even more on the side of setting sensitivities too high. Given the potential to save millions of additional lives, this is no time to turn down the sensitivity of our environmental alarm.

References and Notes
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Supporting Online Material
www.sciencemag.org/cgi/content/full/301/5637/1187/DC1
SOM Text
Table S1