Can the Precautionary Principle Manage Risks Effectively?

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1. Technology and Risk Reduction in the Twentieth Century

In the past two centuries, despite — or is it because of ? —economic growth and technological change, life threatening risks have one by one been reduced or eliminated in the world's richer nations (Goklany 2007). The 20th century saw the United States' population multiply by four, income by seven, carbon dioxide emissions by nine, material use by 27, and chemical use by more than 100. Yet people are living longer, and healthier. Life expectancy increased from 47 years to 77 years. The disability rate for seniors declined 28 percent between 1982 and 2004/2005 (Manton et al. 2006) and, despite quantum improvements in diagnostic tools, major diseases (e.g., cancer, and heart and respiratory diseases) now occur 8–11 years later than a century ago (Fogel 2003).

Such improvements are a global phenomenon. The developing world's population suffering from chronic hunger declined from 37 percent to 17 percent between 1970 and 2001, despite an 83 percent increase in population. That, supplemented by wider knowledge about basic hygiene, greater access to safe water, sanitation, vaccines, antibiotics, pasteurization, basic health services and new medicines, helped more than double average global life expectancy from 31 years in 1900 to 67 years today.

Regarding the environment, death and disease from various water related ailments were reduced dramatically. During the 20th century, partly due to chlorination, cumulative death rate from typhoid, paratyphoid, dysentery and various gastrointestinal diseases dropped 99.5 percent in the US. Malaria dropped 99 percent because of DDT spraying, better nutrition and draining of wetlands. Similarly, air quality in richer countries has improved steadily. Outdoor particulate matter and sulfur dioxide concentrations in US urban areas peaked in the 1960s or earlier, while indoor concentrations—more relevant from the public health perspective because people spend most of their time indoors—have been improving since at least the 1940s.

In developing countries, however, many environmental indicators are deteriorating, but their performance is ahead of developed countries at equivalent levels of development largely due to globalization of technology and knowledge. In 1913, average US income was $5,300 (in constant 1992 dollars, adjusted

for purchasing power), infant mortality was about 100 per 1,000 live births and life expectancy was 52 years, whereas China in 1998 had an average income of $3,200, infant mortality was 31 and life expectancy was 70.

The worldwide reductions in deaths and disease since 1900 despite increased population, energy, and material and chemical use are due to broad dissemination (through education, public health systems, trade and commerce) of numerous new and improved technologies in agriculture, health and medicine supplemented through various ingenious advances in communications, information technology and other energy powered technologies. While these technologies may have created new or exacerbated some existing risks, the above evidence indicates that they reduced overall risks by a greater amount.

Yet, even as major risks to health and well-being were being reduced, expectations rose even faster and the safer we have become, the more we worry about the remaining risks, and despite the improvements from technology, many people are deeply suspicious of technology. But as larger and more obvious risks are reduced, it becomes harder to identify the causes of remaining risks and to establish cause-and-effect relationships, especially at the lower levels many contaminants are currently found in the environment. Consequently the public policy arena is riddled with conflicts over minutiae of risk analyses such as whether or at what levels Alar on apples, arsenic in water, or acrylonotrile in food are safe for consumption. The need to resolve such conflicts and surrounding issues powered a vast expansion of the "regulatory state" during the past few decades, largely to manage health, safety and environmental risks from technology. Such concerns also spawned the "precautionary principle."

The precautionary principle is a modern day articulation of the old saw, "Better safe than sorry". Depending on its precise wording, the principle may allow for—or, alternatively, require—regulation of an activity or technology that might create serious or irreversible environmental, health or safety threats even if the existence (and magnitude) of these new risks is scientifically uncertain. Some version of this principle is enshrined in at least 14 international agreements, including the United Nations Framework Convention on Climate Change, the Rio Declaration, and the Convention on Biological Diversity.

Although there are many versions of the precautionary principle, all are premised on the notion of reducing, if not eliminating, risks to health, safety, and/or the environment. Therefore, I will interpret the question posed in this chapter's title as asking whether the principle is an effective tool *to reduce overall risks*, rather than an effective tool to merely regulate risks.

To appreciate the distinction between the two questions, consider the European Union's experience with genetically modified (GM) crops. The EU's approach, which embodies a "strong" version of the

principle, has ensured low rates of adoption of GM crops within Europe, but it doesn't follow that this has reduced overall environmental or health risks, the very reason for the precautionary principle. But the US approach, which incorporates a moderate version of the principle (requiring governmental approval prior to their commercial cultivation), has led to rapid adoption of GM crops and brought significant environmental benefits (relative to conventional crops). These benefits include higher yields (which reduces habitat lost to agriculture, the most important threat to biodiversity), lower pesticide usage, increased no-till cultivation (which reduces soil erosion, water pollution, and carbon emissions), and increases in biodiversity (Marvier et al. 2007). Thus, while the EU's version of the precautionary principle has effectively limited GM crops, by prolonging riskier practices, it's been environmentally counterproductive.

The arguments for and against the precautionary principle and its various versions are discussed in Section 2. Section 3 compares cost-benefit analysis (CBA) and precautionary principle–based approaches to managing risks. Section 4 offers a practical set of guidelines combining the precautionary principle and elements of CBA to ensure that risk management decisions indeed reduce overall risks to human and environmental well-being in ambiguous or uncertain situations where policies or actions might increase some risks while reducing others. Conclusions are set forth in Section 5.

2. Weak, Strong or No Precautionary Principle?

Both proponents and opponents of the precautionary principle have often argued that it substitutes for cost-benefit analysis or its subset, risk analysis. Its proponents view this as one of its most attractive features. The New York Times' review of the best ideas of 2001 hailed it as "revolutionary" and superior to the risk-analysis paradigm employed by US society and the World Trade Organization for managing technological risks. But opposition to the principle has coalesced around precisely the point that it seemingly rejects risk analysis and CBA.

Weak forms of the precautionary principle allow for regulating technology where "full scientific certainty" of harm from that technology is lacking. But since decisions are routinely made in both the public and private spheres despite the lack of "full scientific certainty," such formulations are uncontroversial, which accounts for the broad acceptance of the weak versions (Mandel and Gathii 2006).

Strong versions of the principle mandate regulation, if not an outright ban of the technology under consideration unless it's proven "safe." These versions require proponents of the technology to bear the burden of proof demonstrating its safety. But how safe is safe enough?

Consider that no activity is completely risk-free. Whether one, for instance, merely stands on the kerb waiting for the light to change or steps off it to cross the street, there is a finite probability of getting hit by a passing vehicle. Second, as noted, historical experience suggests that even where technologies introduce new risks, they frequently reduce, if not eliminate, existing risks of greater magnitude (which is why current generations live longer and healthier than their predecessors).

For example, DDT used for indoor spraying to reduce death and disease from malaria might, however, show up in wildlife populations, with potentially adverse consequences (Goklany 2001). Similarly, GM crops on one hand could reduce the environmental impacts of conventional agriculture and advance public health by enhancing the quantity and nutritional quality of food. But GM crops could also increase the possibility of gene escape into the wider environment with potentially adverse environmental consequences. For example, if the engineered gene is designed to be resistant to a pesticide, it could potentially create "superweeds."

In light of such competing and plausible sets of risks, should the burden of proof be shouldered by the proponents of the new technology or defenders of the *status quo*? Does the precautionary principle require action to regulate the new technology, or inaction—thereby effectively endorsing existing technology despite its risks?

But the various versions of the precautionary principle do not provide any practical guidance on how to minimize overall risks and avoid counterproductive outcomes. Consider, for instance, that although the strong version was invoked by environmental groups to support a global ban on DDT because of its environmental impacts, it could also be used to encourage DDT use because of its global public health benefits, including significant reductions in the 300-500 million incidences and a million deaths associated with malaria annually, mainly in Africa.

Because of such contradictions inherent to the strong versions, Sunstein (2005) rejects the strong version as "paralyzing." Instead, he would manage risks based on three elements. First, he would use CBA to evaluate all relevant risks resulting from all options, including the action and inaction options. Second, he would use an Anti-Catastrophe Principle, although he would limit its reach if the costs of reducing harm is excessive or scarce resources would be diverted from more pressing tasks because expensive regulation can actually drive up risks to life and health. Third, he would employ "libertarian paternalism" to direct people's choices toward welfare-promoting activities while preserving freedom of choice.

Many analysts who are otherwise favorably inclined toward the strong version apparently recognize the force of the above arguments, and espouse moderate versions of the principle. They would, accordingly,

temper their precautionary principle by requiring regulatory stringency to be proportional to the magnitude and nature of threat, sensitive to costs, and changeable in light of new information (Dickson 2005; Mandel and Gathii 2006).

Some analysts also argue that shifting the burden of proof to proponents of new technologies may freeze the *status quo* and stifle technological innovation which has historically been instrumental in reducing existing risks to public health and the environment. The EU experience with GM crops lends credence to such fears.

Moreover, the standing of the precautionary principle as a legitimate risk regulation tool has been hurt by the claim once advanced by environmental groups that it justified a global ban on DDT despite its demonstrated effectiveness in reducing malaria. This claim, based on concentrating on its environmental costs while downplaying its public health benefits, fuels suspicions that the principle can be used (or abused) to cherry pick which risks one may focus on during regulatory inquiry and regulation.

Burden of Proof

One issue related to the application of the PP is who should shoulder the burden of proof. Should it be the proponent of technological change or the defender of the *status quo*? The regulator or the regulated entity?

In today's world, unless the technology produces a novel product with hitherto unknown physical and chemical properties, it is likely that in rich countries at least, it has to obtain some approval from one or another government agency under pre-existing environmental, health and safety regulations. GM crops, for example, have to get approval prior to testing and commercial cultivation. By default the burden of proof is on the proponent of the technology, and given the political economy of the regulatory state, it's unlikely to change in the future. This is because of the tendency of companies to protect themselves from liability and lawsuits by seeking some level of governmental approval, bolstered by the desire to avoid unfavorable publicity. Second, larger companies, in particular, actively court regulation since that would lead to higher barriers to entry into the market for smaller, possibly more innovative upstarts. Third, legislative bodies, government agencies and their officers often seek to expand their power, and future employment possibilities, by filling regulatory vacuums. So any shift in the burden of proof to the regulator is unlikely, and debate over that is mainly academic.

3. The Role of Cost Benefit Analysis in Risk Regulation

The annual cost to the U.S. of regulating environmental and workplace risks has been estimated at $300 billion annually (excluding benefits and voluntary private expenditures), about 40 percent of Canada's gross economic product (Crews 2004).

Is the public getting it's money's worth? Specifically, it gets less risk reduction than it pays for (Sunstein 2002). Some argue that society's resources would be better utilized if cost-benefit analysis (CBA) were used to discipline regulations of risks, noting that CBA also helps answer a critical risk management question, namely, how safe is safe enough? However, if CBA is legally precluded—it is, for example, in the development of National Ambient Air Quality Standards—they would accept cost-effectiveness analysis as the next best solution, although that wouldn't answer the question of what's safe enough.

Sunstein argues that a fundamental problem with the current state of risk regulation is the public itself, and its inevitable influence on decision-making in a democratic society. The general public—by definition, non-specialists in toxicology and risk analysis—relies on "intuitive toxicology" to shape its attitudes and responses toward chemical and environmental risks. But intuitive toxicology is frequently based on misconceptions [e.g., animal carcinogens are necessarily human carcinogens and there is no safe level of exposure to "cancer-causing" agents (equivalent to the "no-threshold" model of carcinogenesis)]; wishful thinking [e.g., natural chemicals are more benign than synthetic chemicals, zero risk is a practicable goal, and reducing one set of risks would not increase other risks]; and even erroneous information [e.g., air, land and water are more polluted now than ever before]. Moreover, they frequently subscribe to dubious propositions, such as conservatism in risk analysis necessarily saves lives rather than diverting scarce resources from pursuing other more worthwhile risks or other gainful uses.

Compounding matters, non-specialists rely on error-prone "mental shortcuts" such as assigning higher probabilities to types of hazards they can readily recall, e.g., nuclear plants are deemed more hazardous because they remember Chernobyl., and an emotionally-driven tendency toward adopting the more alarming of competing narratives regarding a hazard ("alarmist bias"). Moreover, today's technology frequently detects chemicals to levels at which health impacts cannot be reliably replicated, e.g., dioxins may be detected down to 0.1 part per trillion, equivalent to one penny in $100 billion, but since absence of future harm is unprovable, they resort to their mental shortcuts to interpret the significance of such low dioxin levels.

Well-organized and frequently well-funded groups ranging from self-described "public interest" groups to industry attempt to exploit—sometimes, e.g., the Alar case, with brilliant success — the general public's false premises and cognitive failings to create "informational cascades" designed to bolster public demand for their policy agendas, which democratic governments and institutions are conditioned to heed.

Thus, governments devote resources to little, rather than large, problems. Sometimes they react to short term public outcries. Sometimes, being unaware of the harmful, unintended side-effects of regulation, they make matters worse. Consequently, annually the regulatory state could unwittingly be sacrificing tens of thousands of lives prematurely (equivalent to hundreds of thousands of life-years) that could otherwise be saved without increasing total costs of risk reduction activities (Sunstein 2002).

Establishing the primacy of CBA would, Sunstein argues, buffer overly-responsive governments from forces that special interest groups can generate and mobilize to skew society's risk reduction priorities and misdirect scarce resources. CBA, if undertaken by scientifically literate practitioners using peer-reviewed science, could, by providing a full quantitative rendering of both the good and bad consequences of risk reduction proposals, could diminish the likelihood of unintended consequences.

Although some proponents of the precautionary principle recognize that costs should play a role, that the regulation should be proportional to the nature and severity of potential risk, and that choices must occasionally be made between competing risks (Dickson 2005), many remain unconvinced about CBA (Ackerman and Heinzerling 2002; Mandel and Gathii 2006; Arcuri 2006). They argue that cost-benefit analysis requires certainty in order to, first, quantify costs and benefits and, then, to convert them into monetary units and that, in the absence of certainty, cost benefit analysis has to resort to subjective probabilities to estimate risk. They are also skeptical of efforts to convert all consequences, particularly environmental consequences such as species extinction or damages to exceptional ecosystems (e.g., coral reefs), into monetary terms. Third, they argue that the use of discounting in CBA to account for future consequences of a technology "improperly trivializes future harms and the irreversibility of some environmental problems" (Ackerman and Heinzerling 2002). In fact, some would explicitly weigh the scales in favor of the environment over development if, despite uncertainty, the environmental consequences could be irreversible (Arcuri 2006). Fourth, they note that an examination of all relevant risks and options might itself lead to "paralysis by analysis."

CBA advocates, however, recognize that some categories of costs and benefits can't always be quantified or valued in monetary terms. Under these conditions they would use *qualitative* CBA. That would be acceptable to the US Office of Management and Budget (OMB), the agency that oversees CBA undertaken by Federal agencies in support of their regulatory actions. Notably, if qualitative factors are included in CBA, the latter would more closely resemble multi-criteria decision making, which some precautionary principles proponents have raised as a possibility. Also CBA advocates would, to the extent practicable, include consideration of all plausible direct and indirect (including ancillary) costs and

benefits, thus precluding, at least in theory, the possibility of cherry picking ancillary consequences, whether they are costs or benefits.

With these provisos, CBA is appropriately viewed as a methodology to inform, rather than make, decisions. It could be used to ensure that risk regulation fulfills its purpose of reducing overall risks, and there is no reason why agencies, for reasons of transparency and good governance, shouldn't have to show that their regulations' benefits would exceed costs (or explain why not) and show, by analyzing risk−risk trade-offs, that it would not create larger countervailing risks.

Moreover, in response to claims that CBA and risk analysis are undemocratic since such analyses rely on technocratic experts who, moreover, have their own inherent biases, CBA advocates echo Jefferson that "without better [and more reliable] information, neither deliberation nor democracy is possible" (Sunstein 2002: 257).

CBA, moreover, can serve not just as a foil against popular but ill-informed and poorly evaluated actions purporting to reduce risks, but as a prod to advance regulations if benefits outweigh costs. For example, based on CBA, OMB urged the Occupational Safety and Health Administration to consider promoting automatic defibrillators in the workplace to reduce deaths following cardiac arrest.

Finally, with regard to discounting, which is used to compare costs and benefits incurred today against the costs and benefits that would accrue in the future, CBA advocates note that its rationale is rooted in human preferences and behavior manifested in the empirical observation that consumers prefer to enjoy benefits sooner rather than later, and postpone costs (Cropper and Portney 1992). The comparison between future and present-day costs (and benefits) is made via the "discount rate," which reduces future costs (and benefits) to present costs and benefits. Thus, using a discount rate of 4 percent, a benefit that would be worth $100 next year would be worth $96 today.

However, given that discounting allows costs and benefits incurred at different times to be compared on the same basis, it is a necessary evil. The only question—and a hotly debated one—is the magnitude of the discount rate, an issue beyond the scope of this paper.

4. Ensuring that the precautionary principle reduces overall risks

For the precautionary principle to deliver on the promise implied by its name, any policy, regulation or action (or "policy", for brevity) predicated on the principle should not increase overall environmental and

public health risks. In fact, the principle should favor those policies that would reduce overall risks the most.

That objective is easily met if a policy only reduces risks and is cost-free. Clearly we should adopt that policy. Similarly, if a policy only increases risks, the decision is equally simple: avoid that policy. But policy options frequently reduce some risks while increasing or prolonging others (e.g., global bans on GM crops or DDT). Moreover, both positive and negative outcomes are often uncertain.

What do we do in such ambiguous situations?

To ensure that a policy is truly precautionary, one should compare the risks of adopting the policy against the risks of not adopting it (or of the default policy). This inevitably requires comparative risk analysis (or risk−risk analysis). Thus, notwithstanding claims that risk analysis and the precautionary principle are different or incompatible, the latter requires risk−risk assessment to ensure that risks are indeed reduced (Goklany 2001).

Moreover, so that society gets as much risk reduction as it pays for, such risk−risk analysis should be embedded within a broader CBA. Risk−risk analysis itself, like CBA, can be qualitative or quantitative, depending on the available information and associated uncertainties.

The following set of common-sense and ethical criteria have been proposed for use in conjunction with the precautionary principle to ensure that the principle actually reduces overall risks when outcomes are ambiguous or uncertain (Goklany 2002, 2007):

- *Human mortality criterion.* The threat of death to any human being—no matter how lowly that human—outweighs similar threats to members of other species—no matter how magnificent that species.

- *Human morbidity criterion.* Non-mortal threats to human health should generally take precedence over threats to the environment, although there might be exceptions based on the nature, severity and extent of the threat. The first two criteria may be combined into an anthropocentric *public health criterion*.

- *Immediacy criterion*. All else being equal, more immediate threats should be given priority over threats that could occur later. This criterion can be justified by the fact that people tend to partially discount lives that might be lost in the distant future (Cropper and Portney 1992), and that the longer one lives, the greater the likelihood of discovering technologies that will alleviate the threat, enabling one to live longer and healthier (Manton et al. 2006).

- *Uncertainty criterion*. Threats of harm that are more certain should take precedence over less certain harms, all else being equal.

- *Expectation value criterion.* An action resulting in fewer expected deaths should be preferred over one resulting in fewer expected deaths, *ceteris paribus*. Similarly, actions posing lower risk to biodiversity ought to be favored.

- *Adaptation criterion.* Impacts can be discounted to the extent that they can be reduced or nullified by coping or adaptive technologies.

- *Irreversibility criterion*. Greater priority should be given to outcomes that are irreversible, or likely to be more persistent.

Notably, very similar criteria have been proposed for identifying key vulnerabilities to climate change (Intergovernmental Panel on Climate Change 2007: 785).

If after applying these criteria to competing policies (or to a proposed policy and its default) the results are equivocal with respect to the different sets of consequences, one should apply the human mortality and morbidity criteria. Thus, if the action, for example, might directly or indirectly increase net human mortality but improve the environment by, for instance, increasing the recreational potential of a water body, then that action ought to be rejected. Of course, there will be instances where no cut-and-dried answer will emerge readily; for example, if an action might reduce cases of a non-lethal human disease while at the same time potentially killing a large number of animals. In such cases, in addition to considering factors such as the nature, severity and curability of the disease, cost of the disease and/or treatment, and numbers of human and other species affected (factors subsumed in the above criteria, namely, the adaptation, irreversibility and expectation value criteria), the decision should also consider factors such as the abundance of the species, whether it is threatened or endangered, etc.

Let's apply these criteria to the issue of whether there ought to be a global ban on GM crops, as a case example.

In 2000, 850 million people worldwide suffered from hunger and undernourishment and over 2 billion from malnutrition resulting in over 6 million deaths annually. Poor nutritional habits also contribute significantly to so-called diseases of affluence—heart disease, strokes, cancers—killing 23 million more. To reduce the future toll of hunger, malnutrition, and poor nutritional habits, despite the almost inevitable future increase in human population, the quantity and nutritional quality of food must necessarily be enhanced. The faster this occurs—and with greater certainty— the fewer the expected casualties. And

GM crops should help increase the quantity and nutritional quality of food supplies faster and more surely than conventional crops. Given the magnitude of annual deaths involved, even a minor reduction in the 29 million annual deaths from hunger and poor nutrition will provide significant benefits. Therefore, a GM crop ban is more likely to increase deaths due to hunger, malnutrition, and diseases of affluence (Goklany 2007: chapter 9).

Moreover, considering that GM crops have been part of the US diet since 1996 with no proven adverse cases, future adverse health effects of ingesting GM crops are neither certain nor comparable in magnitude to the global toll from hunger and malnutrition. Therefore, a global GM crop ban will likely increase net harm to public health, condemning large numbers to premature death.

Regarding environmental risks, conventional agriculture, with its appetite for land, water, pesticides, and fertilizers, is the major stress on global biodiversity, and a significant source of greenhouse gases. These environmental pressures can be reduced or contained more rapidly (and more certainly) with GM crops because relative to conventional crops, they are likely to increase agricultural productivity faster and with fewer land, water and chemical inputs. Current evidence from the US, China and South Africa shows that GM crops reduce net environmental risks (Goklany 2007; Marvier et al, 2007).

Thus, in aggregate, a GM crop ban would more likely than not increase risks to both global public health and environment. Consequently, such a ban would be poor public policy.

The above criteria have also been used to evaluate precautionary policies such as a global ban on DDT, the implementation of the Kyoto Protocol, and regulation of blood transfusion with respect to risk associated with variant Creutzfeld-Jakob disease (Goklany 2001; Wilson and Ricketts 2004). In the first two cases, it was concluded that contrary to conventional environmental wisdom, those specific policies would in fact increase overall health and environmental risks, thereby violating their fundamental premise, namely, that they are precautionary. The third case found that the regulations were justified.

5. Conclusion

The precautionary principle can be an effective tool for policy makers in regulating risks provided it's coupled with comparative risk analysis to ensure that overall risks do not increase inadvertently. Such analysis should employ criteria to help prioritize and compare countervailing risks based on their nature, severity, magnitude, certainty, irreversibility, and other characteristics. Moreover, since society's resources are scarce while its needs are numerous, such risk−risk analysis should ideally be part of

broader quantitative or qualitative cost-benefit analysis or, failing that, cost-effectiveness analysis. In addition, there ought to be a mechanism for revisiting past decisions in light of new information.

With these embellishments the precautionary principle can effectively manage risks from both emerging or existing technologies as well as reduce overall risks and advance environmental and human well-being even as population and consumption of materials, minerals, and energy continue to inevitably increase. Failing that, the principle could be an equal opportunity barrier to the dissemination, if not creation, of new technologies whether they increase or decrease overall risks, or provide net benefits to society.

Finally, the foregoing suggests an alternative formulation for the principle, namely, "Risk management policies should attempt to minimize net risks to public health, safety and the environment based on the best available scientific information and their net anticipated costs to society." Or more succinctly: "All things considered, thou shalt attempt to minimize net risks at the least cost to society."

References

Ackerman, F., and Heinzerling, L. 2002. Pricing the Priceless: Cost-Benefit Analysis of Environmental Protection, *University of Pennsylvania Law Review* 150: 1553–1584.

Arcuri, A. 2007. "The Case for a Procedural Version of the Precautionary Principle Erring on the Side of Environmental Preservation," *Global Law Working Paper No. 09/04*, available at SSRN: http://ssrn.com/abstract=967779.

Crews, C.W. 2004. *Ten Thousand Commandments: An Annual Snapshot of the Federal Regulatory State* (Competitive Enterprise Institute, Washington, DC).

Cropper, M.L., and Portney, P.R. 1992. "Discounting Human Lives," *Resources* 108 (Summer 1992): 1-4.

Dickson, B. (ed). 2005. *Biodiversity and the Precautionary Principle : Risk, Uncertainty and Practice in Conservation and Sustainable Use* (Earthscan, London).

Goklany, I.M. 2001. *The Precautionary Principle: A Critical Appraisal of Environmental Risk Assessment* (Cato Institute, Washington, DC).

Goklany, I.M. 2002. "From Precautionary Principle to Risk-Risk Analysis." *Nature Biotechnology* 20: 1075.

Goklany, I.M. 2007. *The Improving State of the World: Why We're Living Longer, Healthier, More Comfortable Lives on a Cleaner Planet* (Cato Institute, Washington, DC, 2007).

Hahn, R.W., and Sunstein, C.R. "The Precautionary Principle as a Basis for Decision Making," *The Economist's Voice*: 2.

Intergovernmental Panel on Climate Change. 2007. *Climate Change 2007: Impacts, Adaptation and Vulnerability* (Cambridge University Press, Cambridge, UK, 2007).

Mandel, G.N., and Gathii, J.T. 2006. "Cost-Benefit Analysis Versus The Precautionary Principle: Beyond Cass Sunstein's Laws Of Fear," available at: http://ssrn.com/abstract=822186.

Manton, K. G., Gu, X.L. and Lamb, V.L. 2006. "Change in chronic disability from 1982 to 2004/2005 as measured by long-term changes in function and health in the U.S. elderly population," *Proceedings of the National Academy of Sciences*, 103: 18374-18379.

Marvier, M., McCreedy, C., Regetz, J., and Kareiva, P. 2007. "A Meta-Analysis of Effects of Bt Cotton and Maize on Nontarget Invertebrates," *Science* 316: 1475–1477.

Pollan, M. 2001. *New York Times Sunday Magazine* (9 May 2001), pp. 92, 94.

Sunstein, C.R. 2002. *Risk and Reason: Safety, Law and the Environment* (Cambridge University Press Cambridge, UK:).

Sunstein, C. 2005. *Laws of Fear: Beyond the Precautionary Principle* (Cambridge University Press, Cambridge, UK).

Wilson, K., and Ricketts, M.N. 2004. "The success of precaution? Managing the risk of transfusion transmission of variant Creutzfeldt- Jakob disease." Transfusion 44: 1475–1478.