

Understanding the reallocations in the portfolio of federal R&D expenditures is a quick way to understand what the book proposes. Such a reallocation is needed and Branscomb's proposal is a good place to start thinking about what it takes to make such changes happen.

I have two final notes. First, both books are primarily domestic, political, or organizational analyses. There is little mention and no significant treatment of the bodies of work that explore the relationships between technology and economic growth, the rates of diffusion of technological advance, or technological aspects of trade and investment among nations. This is not a significant problem for either book but it is worth noting.

Second, with a bit of effort there is something significant to be made of the simple difference in titles. Morin's book is about *science* policy while the Branscomb volume is about *technology* policy. There are clearly very important differences between science and technology, and between science policy and technology policy. Indeed, it is possible to argue that many current issues in science and technology policy have to do with the differences between science (insights and information about the workings of the natural world, the common property of humankind) and engineering or technology (technical problem-solving information, often proprietary, usually harnessed for specific goals). From the perspective of most citizens and policy makers, however, the loose community of university, industry, and government scientists and engineers who are the recipients of federal funds for R&D are a single constituency with a single claim on public resources. These two books can do much to help a reader determine how he or she would like to see those resources used.

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Phantom Risk: Scientific Inference and the Law, edited by Kenneth R. Foster, David E. Bernstein, and Peter W. Huber. Cambridge, MA: MIT Press, 1993, 457 pp., NPA.

Phantom Risk skillfully guides the reader through the state of scientific knowledge regarding 16 highly publicized controversies in technological risk and uncertainty, including Bendectin, video display terminals, dioxin, and polychlorinated biphenyls. It provides a clear and accessible analysis that penetrates the superficial and sometimes distorted coverage provided by the popular media. The book changed my beliefs about many of these alleged hazards. Like most citizens, I had read about the initially alarming evidence of risk, but I wasn't aware of subsequent studies that often challenged the more dire predictions. As a result, my world feels a little safer for having read *Phantom Risk*, and I'm grateful. (On the other hand, a fascinating chapter by Bruce Ames and Lois Gold reassured me about the risks of DDT and chloroform, but destroyed my blissful ignorance of the natural pesticides in celery and broccoli.)

Beyond its specific focus on technological risks, the book is a useful primer on research methodology. The chapters nicely illustrate how leading scientists sleuth their way through a complex body of evidence. A running theme illustrates a principle that is rarely understood by nonscientists: scientific

understanding is a gradual emergent property of a collective body of research; no single study is ever definitive. *Phantom Risk* also devotes considerable attention to the inevitable tradeoffs among fallible methodologies; in particular, the tension between controlled experiments on animals, which provide high internal validity but questionable external validity (in the language of Cook and Campbell [1979]), and epidemiology studies, which provide high external validity but are subject to multiple, conflicting interpretations.

I do have some quibbles about the book's treatment of what Cook and Campbell refer to as *statistical conclusion validity*. Specifically, while the book is to be commended for its clear exposition of the importance of avoiding Type I or false positive error, the authors show much less sensitivity to Type II statistical errors, or false negatives. It is true that the traditional use of the 0.05 significance level reflects a view that false positives are more harmful to scientific progress. But of course one can reduce the Type II error rate without elevating Type I error by increasing statistical power, through the use of larger sample sizes, more reliable measurement, multiple indicators in a latent variable measurement model, and the careful use of meta-analytic techniques. There is ample evidence for a scandalously low level of statistical power in the social and health sciences (see Cohen, 1988). A propensity for Type II errors, or false negatives, is particularly troubling in the area of risk assessment, where lives may be lost if we fail to detect a real but low-probability hazard (see Shrader-Frechette, 1991).

Curiously, despite its sophisticated presentation of scientific reasoning, *Phantom Risk* does not always hold itself to its own high methodological standards in its evaluation of the tort system. A major theme of the book is that the tort system is quite inept at handling scientific evidence. The authors suggest that in the disputes in question, the plaintiffs based their claims on inadequate evidence and faulty inferences that the tort process was ill equipped to ferret out and may even have encouraged. In essence, the book itself acts as a plaintiff, making a claim for harms allegedly caused by a negligent tort system populated by lawyers and experts who are at best ignorant and at worst greedy and dishonest. The irony is that in doing so, the book relies on standards of evidence and methods of inference that are no better—and in some cases worse—than those of the plaintiffs in the cases it describes.

First, in its critique of the tort system, the book relies primarily on case studies, for that's all any given lawsuit, jury decision, or appellate court decision provides. But of course the book itself is quite critical of case studies as a means of testing causal hypotheses, and rightly so. We simply cannot infer anything conclusive about the tort system's competence by examining single cases. A demonstration that a given judge was inept or a given jury was befuddled tells us nothing about the performance of the tort system *as a system*. At best, it refutes the hypothesis that the system is perfect, but no one believes that anyway. Admittedly, at various points in the book, the authors discuss groups of lawsuits involving the same issue, but with the case as unit of analysis, the sample sizes are simply too small to be probative. (Class action suits and other case aggregations don't help us here, because they fail the criterion of independent sample units.)

Even if we ignore sample size considerations, the discussions of actual litigation patterns fall short of epidemiological standards. At best, we might

charitably characterize some of the inferences as retrospective epidemiology, but as several of the authors point out, a good retrospective design requires adequate case controls, and there are none here. In essence, the book is guilty of the *confirmatory bias*, an unjustifiable reliance on a skewed sample of cases that can't possibly falsify a hypothesis. If we want to examine whether Bendectin increases the risk of birth defects, it isn't enough to show that some mothers who used Bendectin had children with birth defects; we need to know the *relative risk*, the incidence of risk in an exposed population to that in an unexposed population. In the same way, if we want to establish that the tort system is negligent in its handling of cases involving scientific evidence, we can't just cite ineptly adjudicated cases, we need to know the relative risk of erroneous verdicts in cases with and without scientific evidence. Just as some children have birth defects in the absence of Bendectin, some plaintiffs' theories wrongfully prevail in nonscientific tort disputes.

A further inferential concern involves the *hindsight bias* (Fischhoff, 1976), the tendency for our knowledge of outcomes to skew our perceptions of the events that preceded them, which can lead us to hold decisionmakers accountable for an understanding of the facts that they couldn't have had at the time they made their decisions. In *Phantom Risk*, the hindsight bias applies with varying force across the many court decisions that are presented. In many of the cases, one can reasonably argue that the decisionmakers in question should have done better; the state of knowledge at the time of their decision was sufficiently clear. But this isn't always so apparent. Many studies cited in the book are dated well after the relevant suits were filed, settlements were reached, or verdicts were provided. Admittedly, there is often a sizeable lag between the date a study is known to an expert community, and the date it appears in a journal. But it can also take years after a study appears to reach scientific consensus on its interpretation.

This isn't to say that we can't study the tort system in a scientific manner; the empirical study of tort litigation is a burgeoning area of social-scientific inquiry (Hensler, 1988). Indeed, there are some interesting parallels between the science of risk assessment and empirical research on torts; for example, the role of rat experiments in the former and mock jury experiments in the latter. This is not meant to disparage mock jurors, but as with rat studies, the very artificiality that makes mock jury experiments a powerful tool for testing causal hypotheses raises concerns about the generalizability of the results (MacCoun, 1993). So we must look for convergence between our experiments and "epidemiological" analyses of statistical patterns across actual cases.

Admittedly, we are still quite ignorant about the behavior of the tort system. We need to learn more about how well lawyers, jurors, and judges perform their roles in cases involving scientific evidence. It isn't very helpful to hold the system to a standard of perfection; we need to compare it to the alternatives. For example, juries do make mistakes, but we can't simply assume that judges or experts will always do better; juries are superior to judges and experts with respect to some criteria and inferior with respect to others (MacCoun, 1993). We also need to learn more about the relative effectiveness of alternative mechanisms for compensation and deterrence, including market discipline, regulatory policy, and social insurance approaches.

Given our ignorance, one might reasonably argue that my criticism of *Phantom Risk* is a bit unjust, that the authors shouldn't have waited for better evidence to criticize the tort system and its handling of scientific

evidence. After all, real parties are suffering real consequences right now, and it may seem unfair to wait for better evidence before we point fingers at culprits. But of course, this is precisely how most of the plaintiffs who file lawsuits like those in *Phantom Risk* feel about their situation. In their view, they are suffering serious harm, and if they wait for better evidence before doing something about it, they won't get the relief they need, and others may suffer similar harm.

This leads us to a paradox: *Phantom Risk* doesn't always meet its own standards of scientific inference, but if we grant it a reprieve on the grounds of urgency, it seems only fair that we excuse, on the same grounds, the very litigation the authors criticize. In my view, many of the book's claims against the tort system are plausible (if unproven) but I'd argue that the lawsuits they document were similarly plausible when filed. While I share the book's view that the issue is too serious to ignore, I'd apply that view with equal force to the plaintiffs' concerns. I would hope we can show compassion for citizens' efforts to seek compensation and deterrence while we encourage scientific efforts to ensure our physical safety and our ability to provide fair, accurate, and efficient justice.

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Public Reactions to Nuclear Waste: Citizens' Views of Repository Siting, edited by Riley E. Dunlap, Michael E. Kraft, and Eugene A. Rosa. Durham, NC: Duke University Press, 1993, 332 pp., \$24.95 paper.

Toxic Circles: Environmental Hazards from the Workplace into the Community, edited by Helen E. Sheehan and Richard P. Wedeen. New Brunswick, NJ: Rutgers University Press, 1993, 277 pp., \$45.00 cloth.

An extensive body of research documents that the focal topics of these two volumes—nuclear waste for the Dunlap et al. book and toxic, environmental