# SUSTAINABILITY, RISK, AND PROTECTION

**Jason F. Shogren** and **Thomas D. Crocker**
*Department of Economics, University of Wyoming, USA*

**Keywords**: Risk, valuation, perception, self-protection, self-insurance.

## Contents



## Summary

This article examines the behavioral underpinnings of risk, sustainability, and environmental protection. Consideration is given to how private citizens and governments confront the challenge of finding reasonable answers to questions about how people perceive risk, how they make choices under risk, and how they value risk reduction. Also considered is how society can manage and regulate risk rationally.



## 1. Introduction

A goal of sustainability through environmental protection is to reduce risks to humans and the environment. By risk is meant the combination of two elements—the chance that a bad event might happen, and the consequences that are realized if a bad event actually does occur. Athough human actions to improve human lives are usually not intended to create risk, pollution is generated pollution and accidents do happen—cars pollute, oil spills, technology fails. How and when and where and by how much define the gambles are created in a modern economy. More often than not the risks taken generate worthwhile rewards—new medicines, new transportation, new communication systems. However, sometimes things go wrong—Chernobyl, Bhopal, Love Canal, or the choices made are feared to have put society on the wrong path—loss of biodiversity, inhospitable climate change.

It must be recognized that a zero-risk society is a noble but unattainable goal. The costs to eliminate all risk to everyone are simply too great. Even if it is believed that a monetary value cannot be attached to human pain and suffering, human actions say something different. If there was a real willingness to pay any price to reduce risk to zero, society would, for instance, impose a 4-mile speed limit for all roads and highways. Everyone would drive slow enough so that no one would ever die from an automobile accident, except perhaps from boredom. Such a rule will never be seen. The costs per life saved from driving so slowly are too great for most people—people are willing to trade-off more risk for quicker travel time. Similar trade-offs are made all the time in jobs, recreation, and lifestyles. As such, understanding the nature of health, safety, and environmental risk, and looking for effective strategies that reduce risk without curtailing the rewards of modern life are essential for better public policy.

This article examines the behavioral economic underpinnings of risk, sustainability, and environmental protection, aiming for a general discussion rather than technical review of decision theory. Aspects addressed are how private citizens and governments confront the challenge of finding reasonable answers to these questions about rational risk policy—how do people perceive risk, make choices under risk, how do they value risk reduction, and how can society manage and regulate risk rationally?

## 2. Choice under Risk

Choice under risk has captivated people at least since the time humans "discovered" that gambling was fun—and although ancestral humans could buy a thrill, they had to wait until the Renaissance before witnessing the development of a systematic theory of probability. Until that time, they seemed to think that people did not create much of their own luck, and fate was the master. Their lives were linked much more closely to nature, and much more exposed to its whims. Crops failed and children died without seeming reason. Most people were simply too busy trying to survive to ponder the systematic nature of risk.

As people began to grasp that they could use free trade to double or triple the value of the wealth they created, the desire to master risk began in earnest. More trade meant more wealth and more risk. Trading partners separated by unpredictable oceans had an incentive to understand how to manage and control risk. As unruly trade routes turned into world wars and global stock and bond swaps, the gains from risk assessment and management as practical arts increased. Those who had a sophisticated appreciation of the behavioral underpinnings of risk had a better chance of winning real and metaphorical battles. This holds for environmental risk too.

To follow the intellectual history of understanding how people make choices under risk, consider three gambles: gamble X is a certain individual payment of $30—a sure bet; gamble Y is a coin flip in which $100 is won with a heads, and $100 lost with a tails; and gamble Z is a roll of a die in which $2000 is won if a #1 is rolled, $1000 is won with a #2, and $500 is won with a #3, while $0 is lost with a #4, l$1000 is lost with a #5, and  $2000 is lost with a #6.

Early theorists speculating on how people make choices under risk thought that many people would prefer the gamble with the highest expected value—the probability weighted average of all possible outcomes of the gamble. Gamble Z has the highest expected value, but it is observed that many people shy away from gamble Z and take gamble X instead. The old adage that a bird in the hand is worth two in the bush reflects the prudent strategy to go for the sure thing.

But why does the gamble with the lower expected value attract some many people? In the eighteenthcentury, Nicholas Bernoulli devised an ingenious example to show why. His St. Petersburg paradox works as follows. Suppose the following proposition is offered. A gamble can be bought into on a fair coin toss. If a head comes up on the first flip, \$2 is earned; if it takes two flips to uncover a head, \$4 is earned; if it takes three flips, \$8 is earned; if it takes four flips, \$16 is earned; five, \$32; six, \$64; seven, \$128; and so on. What is the maximum someone should be willing to pay to buy into this gamble?

Most people will say they will pay something much less than infinity, even though infinity is the expected value of this gamble:

Expected value = [1/2] chance of \$2 + [1/4] chance of \$4 + [1/8] chance of \$8 +…= \$1 + \$1 +\$1 + \$1 + \$1 +…= infinity.

So it seems as though people should be willing to pay a lot more than they probably say they would. Most likely they would say that they would pay a few dollars. Why? One reason is because the variance of the gamble is also infinite. Variance is often considered synonymous with risk, because it reflects the potential volatility of the outcome. The variance reflects the distribution around the expected value. More variance implies more chance that bad states—low payoff outcomes—will be realized.

Nicholas's cousin, Daniel Bernoulli, soon offered a reason why people will pay much less than infinity for a gamble with infinite variance: a gain of \$2000 is not necessarily worth twice as much as \$1000. That is, people seem to have diminishing marginal returns to wealth. This means that even though more money is preferred to less, the last dollar earned gives less satisfaction than the first dollar earned. Daniel Bernoulli's key insight is that a person's "utility (the degree of satisfaction in possessing wealth or goods) resulting from any small increase in wealth will be inversely proportionate to the quantity of the goods previously possessed."

Increased wealth increases total utility at a decreasing rate, which is why the utility function is curved. Therefore, gambles with high variance are less attractive—the gain from an extra dollar added to individual wealth is smaller than the loss from an extra dollar taken away. One example of a useful utility function with this property is:

$u(w) = (w)^{1/2}$, where $u$ = utility, and $w$ = wealth.

For instance, wealth of \$10 000 creates a utility level of 100, while wealth of \$1 000 000 creates a utility level of 1000. A 100-fold increase in wealth increases a person's utility by only 10-fold. When a person acts this way they are said to be risk averse. A risk averse person if more likely to take a certain payoff over a fair bet—a gamble in which the expected value is zero, e.g., 50:50 odds to win or lose \$1000. A risk loving person prefers a fair bet to a certain payoff equaling the expected value of the gamble. A risk neutral person is indifferent to the choice between a gamble and certain payoff equaling the expected value of the gamble.

Bernoulli's insight was formalized into a modern analytical framework called "Expected Utility theory" (EU). Since its introduction in the 1940s by the mathematician von Neumann and the economist Morgenstern (1944), EU theory has been the most successful model of how people make decisions under risk. The formal theory of expected utility reflects the idea that people make choices about risk based their beliefs about the probability that good and bad events will be realized, the consequences of good and bad events, and the utility or satisfaction a person gets from the consequence that is realized. Despite limits to the EU model, which will be discussed later, analysts use the model because it is intuitive and tractable.

The next step in the development of the expected utility model is to account for a person's ability to influence the risk confronted, either privately and collectively through market insurance, self-protection (or mitigation) and self-insurance (or adaptation). A person is not helpless against the risk. There are more options than moving away. Market insurance can be purchased against illness. Investment can be made in different risk reduction strategies to change the odds of suffering from some illness caused by air pollution—an air filter can be bought for the person's home, or the person can at better and exercise more. Actions taken can reduce the likelihood that the bad state will occur, or reduce the severity of the state if realized or do both. Actions to reduce the likelihood of illness are referred to as self-protection or mitigation; actions to reduce the severity are self-insurance or adaptation.

The economic problem is now more complicated. If a person selects the level of self-protection and self-insurance that balances the extra gains obtained from lower odds of illness and less severity with the costs of protection and personal insurance,

$$EU = \pi(z)u(w - z - x) + (1 - \pi(z))u(w - D(x) - z - x),$$

where $\pi = \pi(z)$ is the probability of the good state which depends on the level of self-protection, $z$; and $D(x)$ is the severity of illness which depends on the level of self-insurance, $x$. Including the private ability to reduce risk is helpful in understanding choice under environmental risk, because these actions link risk assessment with risk management. Account must be taken of these actions to measure risk accurately and to manage risk effectively.

Although risk assessment has amassed a useful record of estimating potential threats to humans and nature, one problem permeates the risk assessment literature—the under-emphasis on how people adapt to the risk they face or have created. Over the last decade of the twentieth century scientists have increasingly acknowledged that environmental risk is endogenous. People can influence many of the risks they confront. Examples abound. People move or reduce physical activities when air pollution becomes intolerable. They buy bottled water if they fear that their drinking water is polluted, and they apply sunscreen to protect their skin from UV radiation. A person can invest in a water filter, move, buy a membership to a health club, jog, eat food low in fat and high in fiber, or apply sunscreen; each choice altering his risk to health and welfare. How a person invests resources to increase the likelihood that good things happen and bad things do not depends both on that person's attitudes towards risk and is ability to reduce risk.

Of course, cases do exist in which people have little time to react to protect themselves, such as in the Chernobyl situation. Some people have argued that the problem can be redefined so that risk is independent of human action. However, this position is ultimately self-defeating. Consider a situation in which bacterial groundwater contamination threatens a household's drinking water. The probability of illness among household members can be altered if the water is boiled. An analyst could define the situation as independent of the household's actions by focusing solely on groundwater contamination, over which the household is likely to have no control. But this definition is economically irrelevant if the question is the household's response to the risks from groundwater contamination. The household is concerned about the likelihood of illness and the realized severity, and it is able to exercise some control over those events. The household's risk is endogenous because by expending its valuable resources it influences probability and severity.

People often substitute private actions for collectively supplied safety programs. They use: stronger building materials to reduce the damage from tornadoes, storms, and earthquakes; more thorough weeding and crop storage in response to the prospect of drought; sandbagging and evacuation in anticipation of floods; and improved nutrition and exercise regimens to cope with health threats. At the policy level, these private risk reduction choices can affect the success of collective regulations that promote safety. Use of automobile seat belts reduces both the probability and the severity of injury, but their mandatory installation cannot guarantee that passengers will choose to wear them. Highway speed limits also are effective at reducing fatalities only when drivers observe them. At work, rules promoting personal protective equipment (e.g., hard hats) have the same problem—they protect only those workers who wear them. In each case, individual decisions influence both the probability and the magnitude of harm.

Endogenous risk implies that observed risks are functions of both natural science parameters and an individual's self-protection decisions. Given the relative marginal effectiveness of alternative self-protection efforts, how people make decisions about risk differs across individuals and situations, even though the natural phenomena that trigger these efforts apply equally to everyone. Therefore, assessing risk levels solely in terms of natural science can be misleading. Relative prices, incomes, and other economic and social parameters that influence any person's self-protection decisions affect risk. Just as good public policy-based economics requires an understanding of the physical and natural phenomena that underpin choices, good public policy-based natural science requires an understanding of the economic phenomena that affects risk. Accounting for private decisions to adapt can increase the precision of risk assessment. Failure to acknowledge the depths of individual choice in environmental risk will result in excessive economic expenditure at no gain in environmental quality.

-
-
-

**Bibliography**

Allais M. (1953). “Le comportement de l'homme rationnel devant le risque: Critique des postulats et axiomes de 'ecole Americaine.” *Econometrica* **21**, 503-546.

Baron R. (1994). *Thinking and Deciding*. Cambridge: Cambridge University Press. [An overview on the problems and paradoxes behind the psychology of decision making.]

Becker G., DeGroot M., and Marschak J. (1964). Measuring utility by a single-response sequential method. *Behavior Science* **9**, 226–232. [A classic experiment on estimating utility functions.]

Camerer C. (1997). Progress in behavioral game theory. *Journal of Economic Perspectives* **11**, 167–188. [An overview on the theoretical possibilities and empirical realities of game theory.]

Cherry T., Shogren J., and Crocker T. (2000). Rationality Spillovers. *Journal of Environmental Economics and Management* (forthcoming). [An experimental analysis exploring whether the rationality learned in markets transfers over the choices in nonmarket settings.]

Chu Yun-Peng and Chu Ruey-Ling (1990). The subsidence of preference reversals in simplified and marketlike experimental settings. *American Economic Review* **80**, 902–911. [An experiment showing how arbitrage in markets can eliminate anomalous behavior toward lotteries.]

Crocker T. and Shogren J. (1999). Endogenous environmental risk. *Handbook of Environmental and Resources Economics*, ed. J. van den Bergh. Cheltenham, UK: Edward Elgar Publishers. [An overview of choice under uncertainty when people can self-protect and self-insure.]

Crouch E. and Wilson R. (1982). *Risk-Benefit Analysis*. Cambridge: Ballinger Publishing. Co. [A classic review of how to balance the risks and benefits of private and public decisions.]

Ehrenberg R. and Bognanno M. (1990). Do tournaments have incentive effects? *Journal of Political Economy* **98**, 1307–1324. [An empirical examination on how nonlinear payoffs affect behavior.]

Frank R. and Cook P. (1996). *The Winner-Take-All Society*. *Why the Few at the Top Get So Much More Than the Rest of Us*. New York: Penguin USA. [A discussion on how some firms and nations have organized itself as a tournament in which the winner gets the lion’s share of the rewards.]

Grether D. and Plott C. (1979). Economic theory of choice and the preference reversal phenomenon. *American Economic Review* **69**, 623–638. [An economists’ reevaluation of a classic psychological experiment showing inconsistent choices over lotteries.]

Kagel J. (1995). Auctions: a survey of experimental research. *Handbook of Experimental Economics*, eds. J. Kagel and A. Roth, 501–585. Princeton, New Jersey: Princeton University Press. [An overview on the theory and behavior of auction design.]

Kane S. and Shogren J. (2000). Linking adaptation and mitigation in climate change policy. *Climatic Change* **45**(1), 75–102. [A review of how adaptation and mitigation act as substitutes and complements in climate change policy.]

Knight F. (1971). *Risk, Uncertainty, and Profit*. New York: Harper and Row, Publishers. [A classic discussion of choice under risk and uncertainty.]

Lichtenstein S. and Slovic P. (1971). Reversals of preference between bids and choices in gambling decisions. *Journal of Experimental Psychology* **89**, 46–55. [The seminal psychological experiment showing how people make inconsistent choices over lotteries.]

Neuman J. von and Morgenstern O. (1944). *Theory of Games and Economic Behavior*. Princeton, New Jersey: Princeton University Press. [A classic work that lays the foundation for modern theory of expected utility.]

Plott C. (1996). Rational individual behavior in markets and social choice processes. In K. Arrow, E. Colombatto, M. Perlman, and C. Schmidt, eds. *The Rational Foundations of Economic Behavior*, pp. 225-250. London and New York: MacMillan and St. Martin Press. [A discussion on how exchange institutions affect economic behavior.]

Shogren J. and Crocker T. (1991). Risk, self-protection, and ex ante economic value. *Journal of Environmental and Economic Management* **20**, 1–15. [The implications of how a collective reduction in environmental risk is valued given private self-protection.]

Shogren J. and Crocker T. (1999). Risk and its consequences. *Journal of Environmental and Economic Management* **37**, 44–51. [An examination of the consequences of separating economics from biology in environmental policy.]

Shogren J. and Stamland T (2002). Skill and the Value of Life. *Journal of Political Economy* (forthcoming).

Slovic P., Fischoff B., and Lichtenstein S. (1982). Why study risk perception? *Risk Analysis* **2**, 83–93. [An overview of the psychology of how people look at risky decisions]

Starr C. (1969). Social benefit vs. technological risk. *Science* **165**, 1232–1238. [A classic discussion on the nature of voluntary versus involuntary risk.]

Tversky A. and Kahneman D. (1981). The framing of decisions and the psychology of choice. *Science* **211**, 453–458. [A summary of how risky choices are affected as much by how risk is presented as by the risk itself.]

US National Academy of Sciences. (1983). *Risk Assessment in the Federal Government Managing the Process*. Washington, DC: National Academy Press. [The United States definition on how to do risk assessment and risk management, and why they should be separated.]

Viscusi W. K. (1992). *Fatal Tradeoffs*. Oxford: Oxford University Press. [A collection of essays on the rational regulation of risk.]

Waller R. and Covello T. eds. (1984). *Low Probability/High Consequence Risk Analysis*. New York: Plenum Publishers. [An overview on how people think about risks with low odds but extremely high severities.]

**Biographical Sketches**

**Jason Shogren** is the Stroock Distinguished Professor of Natural Resource Conservation and Management, and is a professor of economics at the University of Wyoming. His research focuses on the behavioral underpinnings of private choice and public policy, especially for environmental and natural resources. Before returning to his *alma mater*, he taught at Iowa State and Yale. In 1997, Shogren served as the senior economist for environmental and natural resource policy on the Council of Economic Advisers in the White House. Currently, he serves on the Environmental Economics Science Advisory Board for the US Environmental Protection Agency, and the Intergovernmental Panel on Climate Change. Governor Geringer recently appointed him to Wyoming's Environmental Quality Council. Shogren is also on the advisory committee for *Enlibra*, the Western Governors Association's new doctrine for environmental management. He was an associate editor of the *Journal of Environmental Economics and Management*, and the *American Journal of Agricultural Economics*. Recent publications include *Environmental Economics* (Oxford University Press, 1997), *Private Property and the Endangered Species Act* (University of Texas Press, 1999); *Endangered Species Protection in the United States* (Cambridge University Press, 2001); and papers on risk, conflict, cooperation, valuation, environmental policy, and experimental economics. The American Association of Agricultural Economics selected his essay with J. Tschirhart on the Endangered Species Act at 25 as the Best Choices Article for 1999.

**Thomas D. Crocker** is the J. E. Warren Distinguished Professor of Energy and Environment in the Department of Economics and Finance at the University of Wyoming. He earlier held faculty appointments at the University of Wisconsin and the University of California, and a visiting appointment at the Pennsylvania State University. He was also the founding director of the School and the Institute of Environment and Natural Resources at the University of Wyoming. Among his nearly 150 refereed publications are the original proposal for an analysis of tradable emission permits, the first empirical application of the Coase theorem, and two of the initial treatments in environmental settings of the principal agent problem. He also contributed to the initial development of environmental valuation techniques, especially the hedonic technique. Recently his research has focused mostly on the ways in which ecological and economic systems mediate each other's responses to change, endogenous risk, and the impact of environmental change upon human capital formation. His current work focuses upon the determinants of internal household environment and their effects upon child development.