Uncertainty in Risk Assessment,
Risk Management, & Decision Making

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VALUE AND FUNCTION OF INFORMATION IN RISK MANAGEMENT

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The motto "Better Living Through Chemistry" has its darker side as we discover the unwanted consequences of some very desirable applications of many pesticides, preservatives, and pharmaceuticals. The hazard that we encounter are in the form of toxicity, carcinogenicity, and mutagenicity. The hazards with their associated risks range from the negligible to substantial increases over standard morbidity and mortality.

It has become customary to think of risk in terms of frequency of occurrence or probability as well as a measure of the magnitude of the consequences should the hazard materialize. We shall refer to this bilinear construct (1) as theoretical risk to emphasize its scientific provenance as distinguished from the subjective perception of risk.

Theoretical risk levels in order of their severity can be organized in four categories: (a) zero risk; (b) de minimis risk; (c) acceptable risk; and (d) worst-case scenarios. In this scheme zero risk, a target actually specified in various statutes, occupies a privileged position: with zero risk the theoretical and the socially perceived risks are the same. However, perceptions of whether there can be zero risk vary. The statute instructs an agency, e.g., the FDA, to tolerate no risks in a specific area, such as cancer from food additives. For the no risk goal, the first two steps collapse into one--the identification of the offending hazard--the ban of the identified chemical follows automatically. Again, for the case of zero risk, data collection on hazard identification is simplified; there is no requirement to estimate the potency of the chemical or magnitude of the risk; there is no need for quantitative estimates of exposure. This approach affords a vast economy of information collection. Unfortunately, since the enforcement of the regulation is centralized, individuals have little knowledge or motivation to control their exposure and order their preferences.

The notion of zero risk has great intuitive appeal, and the fundamental theoretical concept of an empty class is not problematic. Problems do arise, however, when one tries to verify experimentally that the risk has in fact been eliminated. Any verification must be based on inductive inference rather than on logical necessity. For example, the statement "there is no arsenic in this soft drink" should more properly be

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phrased: Steps have been taken to eliminate all traces of arsenic, however, there are no reliable tests to measure extremely low levels of arsenic."

With this in mind one may define an almost-zero risk as an event that occurs extremely rarely, i.e. almost never, or as the negligible consequence of the exposure to a small but nonzero-hazard. Such a risk is called de minimis, from the dictum de minimis non curat lex, "the law is not concerned with trifles." The question is: what constitutes a trifling risk from both the theoretical point of view and the standpoint of public perception? Is there an absolute de minimis risk? EPA has proposed, a proposal since withdrawn, that in the case of Larvadex the risk of exposure to 0.4 ppm is a "trifle." (2) Does this constitute an absolute risk; and if so, from whence derives the moral and intellectual authority to designate this risk level as de minimis. And finally, what evidence has to be adduced from what is knowable to support the claim of the absolute proposition that a certain exposure level is harmless?

The emotional intensity of the arguments advanced for and against the legitimacy of the notion of acceptable risk, our third category, is indicative of the social conflicts that can be engendered by a policy that would accept a finite risk level as part of a cost/benefit calculus. In fact, one of the issues around which controversies cluster is the very notion of the existence of such a thing called acceptable risk. The issues are refreshingly fundamental: What is knowable about theoretical risks and the public perception of risk; who knows what and who needs to know what. The consistency with which these questions keep reappearing is remarkable. Not since the debates over Heisenberg's Uncertainty Principle have practical matters like the determination of level of risk engendered serious considerations of such arcane concepts as the ontology of knowledge.

The function of information in risk management comes into sharp focus when considering events that have a low probability of materializing but if it should materialize, the consequences would be devastating. Under these circumstances a worst-case analysis is called for in the NEPA legislation, in particular Section 1502.22. The courts have interpreted the requirement for a worst-case analysis to mean that there are situations where the bilinear form of risk representation cannot be applied. Consideration has to be given not to the probability of a catastrophic risk materializing but its possibility. This approach is tantamount to a simple linear--not bilinear--representation of risk.

WHAT IS KNOWABLE TO WHOM

Ordinarily, one does not think of knowledge in ontological categories, although the Greeks and notably Aristotle maintained that only the unchanging is knowable. This unchanging something is substance which is nothing less than God--the unmovable mover. Collingwood (3) notes that a theory of knowledge according to which only the unchanging can be known must be grounded in a metaphysics that recognizes as knowable only the residue which remains after the veil of human perception has been lifted. The quest for substance proceeded simultaneously in two directions. First, it was sought by removing from apprehension all that was incidental and obviously changeable, thereby uncovering the natural world embodied in knowledge now exempt from change. Secondly, it was sought by looking for unchanging relations between changeables. If the required changeless something can be found in one of these quests, the other becomes unnecessary. (4) Both approaches can be found in the risk

analysis literature, where they are referred to as "actual" risk and "comparative" risk respectively.

The analytical objective determination of risk from laboratory experiments, actuarial data and models is identified with actual risk. This is in contradistinction to the application of human judgment which is referred to as perceived risk. Actual risk then is tied to the application of the scientific method which yields replicable results with predictable regularity. Deviations from regularity are attributed to imperfect measurement techniques but not to the intrinsic variability of the underlying phenomenon. Yes, Virginia, the world is stable it is only people who are fickle!! A weaker form of permanence is postulated by comparative risk analysis which avoids the necessity to attach a specific and permanent value to risks. It is the relationship between different risks that are assumed to be stable. For example: the risk from smoking a specific number of cigarettes is compared and equated to the consumption of a certain number of bottles of a soft drink. These comparisons are based on theoretical risks but only the equivalences are assumed to be stable.

Let us divert your attention for a moment from the discussion on risk levels to the schemes which serve to supply meaning to purported explanatory concepts such as risk categories. Toulmin argues convincingly that such categories, if universal, are necessarily embedded in a transcendent representation of nature which gives ultimate intellectual authority to "either an axiomatic system of propositions or a presuppositional system of concepts" (5). These presuppositions determine not only what kinds of conduct we consider right or wrong, but also what kinds of phenomena we regard as puzzling or self-explanatory.

But this intellectual authority is based on positive faith in the scientific method. Alas, the scientific method could not deliver the perennial truths it promised, arguably because of the real diversity in man's beliefs. Consequently there is no rational procedure that would allow us to assert that a risk level of one excess incidence of cancer per 10^6 exposed individuals is de minimis, while one in 10^5 is not. Things are getting pretty confusing by now when the scientific method is alleged to be grounded in faith whereas the perception of risk based on human judgment is non-falsifyable but real.

Toulmin suggests a wayout of those difficulties which are created by the commitment to a universal standpoint of rational judgment. He proposes that "Questions of rationality are concerned, precisely, not with the particular intellectual doctrines that a man -- or professional group -- adopts at any given time, but rather with the conditions on which, and the manner in which, he is prepared to criticize and change those doctrines as time goes on. The rationality of a science (for instance) is embodied not only in the theoretical systems current in it at particular times but also in its procedure for discovery and conceptual change through time."(6)

The link Toulmin observes between natural philosophy and empirical science--between the abstract analysis of possible explanatory forms and their application to actual classes of natural phenomena--is closely related to our central concern over the key relationship between the intellectual ideals of a scientific discipline and its explanatory procedures, concepts, and the theoretical problems. (7)

Concepts, schemes, and systems are implicit in and necessary for thought. A venture which may succeed or fail because we think forward,

i.e., speculate, but understand backwards. Speculative thinking is an attempt to move from the concepts and conceptual schemes in one's own mind to other and novel schemes. Such speculative thinking is initially confusing as one seeks different interpretation; in fact, most all of these excursions go nowhere. Those that succeed, however, show up as changes in paradigms.

This brief excursion was meant to draw your attention to the danger of ignoring the fundamental limitations in our ability to acquire specific knowledge not only because such acquisition is beyond available techniques but also because this information does not exist in the form in which it is sought. To wit the formula the alchemists sought to turn base metals into gold could not be found because its existence was predicated on a view of nature that is, as we now know, incorrect.

THE MARKET: WHO NEEDS TO KNOW WHAT

Restricting himself to economics, Hayek observes that the peculiar character of the problem of a rational social order is determined "...precisely by the fact that the knowledge of the circumstances of which we must make use never exists in concentrated or integrated form but solely as the dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess." (8) It is the amazing ability of markets to operate with this incomplete knowledge that has made them the important institutions that they are. The market has the uncanny ability to integrate the two disparate types of knowledge, the specific knowledge in the hands of the entrepreneur and the decentralized knowledge of the consumer. The economic problem as Hayek points out and mutatis mutandis the rational risk assessment is not merely a problem of how to allocate given resources -- it is rather a problem of how to secure the best use of resources known to any of the members of society, for ends whose relative importance only these individuals know.(9) It is necessary to recognize and accept the fact that in the social problem solving that we have discussed one has to deal with the different categories of knowledge: centralized professional knowledge and diffuse social knowledge. This messy state of affairs is not a provisional imperfection--it is an essential feature of social problem solving.

The market is only one type of social problem solving institution and it is focused on another objective. However, many risks arise in the course of production, distribution, and consumption. Thus, any decisions concerning these activities have implications for risk. The market handles risk in just the same fashion as it handles other attributes of these activities. For example, the risk of an automobile is one attribute of the product along with its horsepower, size, fuel economy, price, etc. Consumers are presumed to prefer less risk and so prefer autos that have this attribute, other qualities held constant. However, it is difficult to get information about the risks of each model; it is also difficult to buy a car with precisely the mix of attributes that one desires. If risk is not a terribly important aspect of the automobile purchase decision, it might have little influence on either buyers or manufacturers. However, in theory, when consumers have information on risk, they can and will act on their preferences; their actions will lead manufacturers to change products to build in the "right" amount of safety (according to the preferences expressed by buyers).

Analagously, workers who face occupational risks are presumed to regard these risk as one attribute of a particular job, along with its wage rate, general working conditions, location, etc. Since workers care

about safety, they can be expected to avoid jobs that are dangerous when they have an alternative or to demand higher wages to compensate for the risk. In theory, workers and employers would arrive at levels of occupational risk that would be correct in the sense that they took account of the preferences of workers and the costs of lowering risk.

One objective that is expressed to this line of reasoning is that workers and consumers really don't care about risk or: they may care about risks in ways that are different from those characterized by analysis. If this were so, they wouldn't care about riskin their voting behavior and regulatory agencies wouldn't have the political power to require risk reduction. Of course, there is a distribution of preferences about risk in the population; a political outcome represents some median safety preference. If a regulatory agency enforced this level, it would be less stringent than about half the population desired and more stringent than half the population wanted. However, if the safety conscious people felt more strongly, they might desire this level of safety. We suspect that this explanation is correct and that a major goal of federal agencies is to protect some people despite their preferences. This also provides a good explanation as to why some consumers or workers are hostile to federal agencies--and why these agencies find some regulations impossible to enforce in some cases.

A more salient objection concerns the cost of gathering an disseminating information in the market. It is difficult and expensive for individuals to acquire risk information about jobs and products. While institutions such as unions and consumer groups gather an disseminate this information, individuals are not as well informed as they could be. This sort of imperfection could lead to getting systematically too little safety or too much.

There are also risks that do not arise in normal economic activity. For example, earthquakes and storms impose risks and have nothing to do (at least directly) with economic activity. Are there market like institutions that can manage these risks? The answer is a partial yes, under some circumstances.

Insofaras actions can be taken to protect against adverse events, individuals are motivated to take the. For example, individuals would be motivated to build a sea wall against waves or a dam against floods. However, these actions require the agreement of many individuals and so there are problems with getting them all to agree, to pay their share, etc. In these circumstances, it is often simpler to use existing governmental institutions instead of having to create what is essentially a new institution for each risk.

Another aspect of protecting against risk is protecting against the financial loss of a storm or flood. This protection typically comes in the form of insurance. There are many companies offering policies to cover the financial losses of fire, flood, storms, etc. In the case of floods, a federal program was created to offer highly subsidized insurance. In general, there is little reason to believe that current insurance companies do not offer adequate protection against the financial loss associated with these sorts of adverse events.

One of the great accomplishments of microeconomic theory has been to explain the role and mechanisms of information collection and dissemination in a decentralized market economy. Since information is expensive to gather, process, and disseminate, major advantages accrue to institutions like the market that minimize the need for collection,

processing and dissemination. Prices, which are easily observed, provide all of the information that individuals need to acquire other than that which each requires because of his special function.

An important characteristic of the market is that consumers' preferences can be manifested in a decentralized fashion and that producers can satisfy the individual preferences of each consumer. There is no need for consensus on a particular product in the sense that everyone has no alternative but to take on that is offered or nothing. Rather, aside from products where so few consumers desire them that production is unattractive, the market produces the types and quantities of each product that consumers desire.

Unfortunately, the more troublesome cases for production and allocation of goods and services are precisely the cases most like the situations involving risk management. Two difficult cases for economic theory are those of "public good" and "spillover effects." The first concern, public goods, occurs when a service cannot be provided to one individual without providing it to all. For such public goods, general concurrance is required, since the same level of national defense must be provided for the entire society. As Lave and Romer(10) show, many risk management decisions have a public good character and so management is inherently controversial.

The second difficulty concerns externalities. These are spillover effects that are unintended and generally undesired. Risk management is replete with spillover effects. It is not surprising that risk management is inherently more difficult than the simple economic models of goods and services.

Little attention has been given to the information requirements of risk management decisions. Since the cost of gathering, processing and disseminating this information is high, it is surprising that it has received so little attention.

The Risk Management Process

Shown in figure 1 in one characterization of the risk management process, beginning with hazard identification and ending with monitoring. The data requirements are characterized in the figure. These can be as informal as thinking about patterns in one's own experience or as formal as a public hearing. For every risk management decision, data are required for each step in this figure. For most public and virtually all private decisions, most of these steps are ignored or only the most rudimentary data are utilized. Major public risk management decisions may require an explicit, full scale analysis of available data or even the collection and analysis of new data. It should be noted that traditional markets perform reasonably well even if the available data are fragmentary--the market does not need perfect information to work--putting it differently: markets fail gracefully rather than catastrophically.

Under a market system, there is o centralized hazard identification, or indeed centralized action of any sort. The hazard would have to be identified by the individual producer, worker, or consumer--or by their agents, such as labor unions or Consumers Union. This is likely to be a slow, expensive process that never informs all relevant parties even about a major risk such as asbestos hazards. Once the hazard has been identified and the actors motivated to do something, each individual who feels the potential for harm must take action to determine how the risk can be lessened, whether the resulting cost is worthwhile, and to monitor

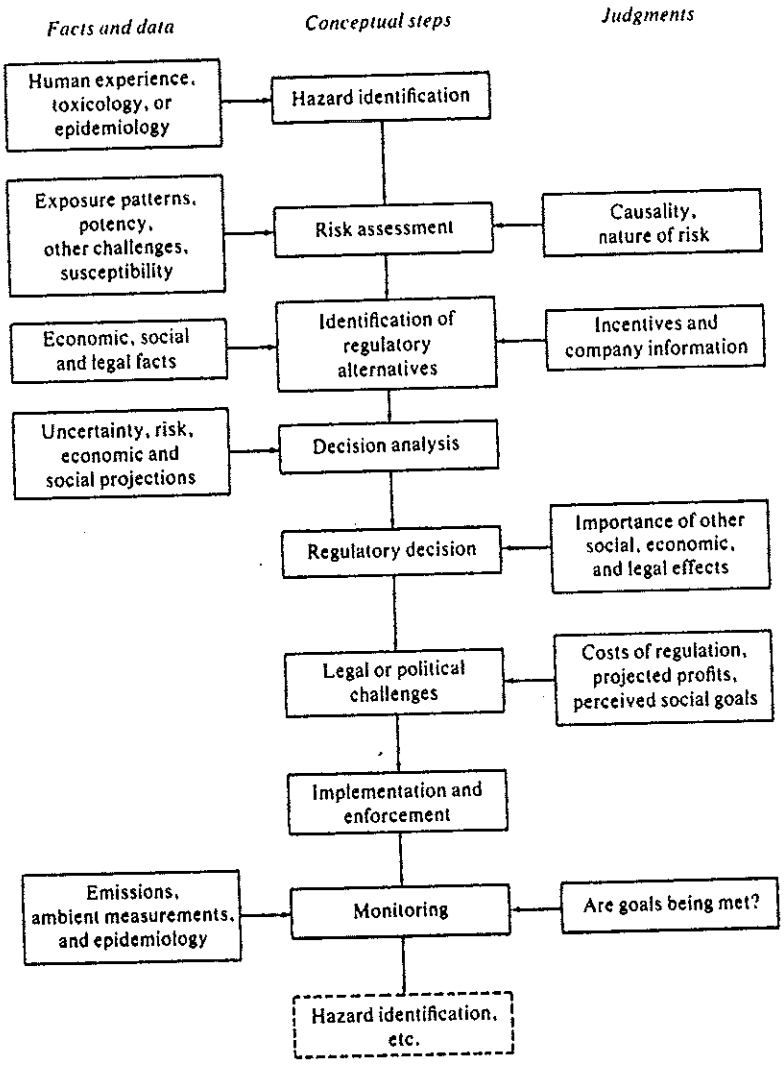

Figure 1

Hazard Management

to ensure that the correct actions continue to be taken. The decentralized nature of the process means that it will be uncoordinated and rough. However, once each actor requires the information, the process should work well since each will be motivated to ensure that the desirable changes are made. Unfortunately, there is no formal mechanism for hazard identification or solution worked out by one individual to be communicated to others.

To summarize, when the risks do not involve public goods or spillover effects, the market can make good risk management decisions. Since the market is a decentralized system, it is not economical in the gathering, analyzing, and dissemination of information. However, since these

processes are done in a decentralized fashion, the individuals who will enforce the solution have the information and thus implementation of the outcome should be relatively easy.

REFERENCES

1. The representation of risk, R, is patterned after the von Neuman-Morgenstern "expected utility index." The index is the product of the probability of a certain outcome times the utility associated with this outcome. If p is the probability of a risk event occurring and C is the magnitude of the damage when the risky event takes place, we write R=pC. This index is linear in both p and C hence the term bilinear.
2. EPA Regulators Take on the Delaney Clause, SCIENCE, 25 May 1984, Volume 224, pp. 851-852.
3. R.G. Collingwood, The Idea of History, Oxford University Press, 1981 p. 42.
4. R.G. Collingwood, The Idea of Nature, Oxford University Press, 1981, p. 12.
5. Stephen Toulmin, Human Understanding, Princeton University Press, 1977 p. 81.
6. Ibid, p. 84.
7. Ibid, p. 6.
8. Friedrich A. Hayek, Individualism and Economic Order, University of Chicago, Midway Reprint, 1980, p. 77.
9. Ibid, p. 78.
10. Lester B. Lave and Thomas Romer, Specifying Risk Goals: Inherent Problems with Democratic Institutions, Risk Analysis, September 1983, p. 217.