Chapter 4. Crisis Management: Coping with the Unexpected

> The practical limitation of knowledge, however, rests upon very different grounds. The universe may be ultimately knowable, ... but it is certainly knowable to a degree so far beyond our actual powers of dealing with it ... It probably occasions surprise to most persons the first time they consider seriously what a small portion of our conduct makes any pretense to a foundation in accurate and exhaustive knowledge of the things we are dealing with. ... The facts [also] suggest a connection with that other age-old bone of contention, the freedom of the will. If there is real indeterminateness, and if the ultimate seat of it is in the activities of the human (or perhaps organic) machine, there is in a sense an opening of the door to a conception of freedom in conduct. Knight, F. H. (1921). *Risk, Uncertainty, and Profit* (Ch. 7).

Frank Knight (1921, ch. 8) introduced the distinction between risk and uncertainty. Some phenomena are sufficiently commonplace and regular that a probability or conditional probability function can be developed for them based on past observations. This can be done, for example, for the dice and cards used in parlor games. For others, uncertainty is so great as to preclude the accurate assignment of probabilities. Knight used "the term 'risk' to designate the former and the term 'uncertainty' for the latter." For the purposes of this book, what is known as opposed to unknown is the distinction of most interest.

Knight's terminology is less important than the conceptual distinction between measured and unmeasured (and perhaps unmeasurable) probabilities for the purposes of this book. Knight's main interest was how settings with known probabilities differed from those where unknown stochastic processes determined outcomes. In the former, he argued, profits tend to be eliminated through competition (on average), including competition between insurance companies and informed speculators, whereas in the later true profits (and losses) would always be possible, even with perfect competition. Both risk and uncertainty broadly affect the organization of all industries and the distribution of income, not simply the financial and insurance industries.

This book, in contrast, focuses on how risk and uncertainty affect public policies chosen by democratic governments. This chapter, nonetheless, like the previous two, overlaps with Knight's efforts insofar as it investigates steps that individuals and small groups can take to deal with unmeasured uncertainty. Both chapters are efforts to provide an explanation for voter demands for social insurance and crisis management grounded in methodological individualism. If large and small crises are everyday events, then systematic methods for dealing with them--to the extent this is possible--will be worked out, and both risk and crisis management will be a significant part of "ordinary" economic and political life.

An Economy with Only Insurable Risks

As a point of departure, it is useful to imagine a world in which there are no unmeasured or unmeasurable probabilities. In such settings, one knows everything that can possibly happen, why it can happen, and the probability that it will happen (that is, the causal chain or conditional probability function involved). This would be true of both one's relationship to nature and with respect to other persons.

Such complete knowledge allows the possibility that a forward looking person could adopt a long term plan on "day one" of adulthood, and simply follow that plan for the rest of his or her life. Such knowledge assumptions and lifetime planning is the usual starting point of most neoclassical economic models. Much of the comparative statics of economics, game theory, and rational choice politics is simply an analysis of how such lifetime plans changes as parameters of the choice setting change. Changes in price, income, taxes, or probability of loss often imply particular changes, and these for the basis of for testing the usefulness of such models of rational choice. In practice, evidence supports most of these hypotheses, but there is always an unexplained stochastic element.

In well-functioning economic markets, competition among such well informed persons would assure that prices would reach their full equilibrium levels, in the Walrasian sense. A variety of insurance markets would exist and their products would be widely used by all risk averse persons to reduce losses from risky events. Moral hazard and self-selection problems would be solved though pricing or complex contracts. Insurance would tend be provided by very large consortiums because of advantages associated with large samples. Any observed difference in rates of return among consortiums, companies, or industries would reflect the risk premiums associated with their industries and/or owner risk preferences. Each probabilistic phenomena, whether insured or not, would be perfectly priced.

All market prices (in competitive sectors) would reflect the material costs of the last units produced. Technological developments would be anticipated and particular inventions, when they occur, would affect those prices in a predictable manner--because the probability of each possible technological development would also be known beforehand. Stock and bond markets would move in lock step, with rates of return among both varying only because of unavoidable, but known, risks such as those associated with sun spots, global warming, and the various mixed strategies adopted by rivals. All employees, shareholders, and bond holders would be paid according to their contribution to the world economy's total output (their risk adjusted marginal value product).

In the short run, the economy in such cases might be said to resemble an old fashioned mechanical clock, as firms, employees, and consumer choices mesh in a precise gear like manner. In the long run, it could be said to resemble an hour glass as capital and knowledge were predictably, if a bit randomly, accumulated through time and the economy (total income and product mix) grew steadily. Differences in income would bethe result of inherited wealth, talent, risk preferences, propensity to work, with perhaps a sprinkling of luck--insofar as someone must win the occasional "lottery," although lotteries per se would be a relatively unprofitable forms of entertainment in such circumstances.

There would be no totally unexpected products, no totally unexpected events, no missing facts or lacuna caused by ignorance. Although one might not know next week's weather, the range of possibilities and their probabilities would be. As a consequence, the economy's trajectory through time would be well understood by all, at least probabilistically.

This core model used in most of contemporary economics, and it is a surprisingly useful first approximation for analyzing a broad range of economic activity in the short run. This efficient market hypothesis is, for example, widely applied in efficient market models of finance (xxxx, xxxx). However, as we all know, surprises do occur.

A Digression on Surprise and Causality

The above model is consistent with a core methodological assumption used by a broad range of social and physical scientists: that everything is caused. In extreme form, this implies that everything that has happened, or will happen, had to happen. Although, it may be acknowledged that the prime mover--for example, the Big Bang--may not have been caused in this sense, everything else has. From that methodological perspective, the dynamics of the universe consists entirely of one-to-one mappings from what came before to what occurred next, and from to what is occurring now to what will occur in the future. Everything that exists today (and tomorrow) had to be exactly as it is.

From this perspective, when a dice is rolled, the number on top--for example, a six--had to be on top, because of the manner in which the dice was thrown, characteristics of the surface on which it landed, air density, gravity, and the rotation of the earth. Nonetheless, this Deistic perspective allows the possibility of surprise, because human ignorance and computational limits exist. A human may not be able predict the result of a particular roll of the dice, because of the complexity of the interactions among factors, or because some factors cannot be perfectly measured beforehand, as with the initial vector of velocity imparted on the die by the dice roller. For those who accept the strong causality principle, "*god does not play with dice*," but both subjectively random events and surprise may nonetheless occur because of failures to understand the causal chains which bind everything and everyone.

The history of science suggests that many causal chains are subtle and many others are complex. Similarly, contemporary chaos theory suggests that causality can be extraordinary subtle and results affected by a host of tiny, extremely difficult to measure phenomena. As the story goes, a butterfly in Asia may cause a hurricane in Florida, (Waldrop 1992). Moreover, some phenomena may be inherently unmeasurable, unknowable. The Heisenberg uncertainty principle (and others similar to it) demonstrates one cannot know everything about small particles, because the act of observation, itself, changes the path of the particle.[35]

This can also be said of many rational choice based theories. A surprise may induce a new theory of financial markets, that will change subsequent investor behavior in ways not fully anticipated. A new macroeconomics theory may change the behavior of consumers, investors, and governments. A new political theory may change the behavior of politicians and voters.

Indeed, a lack of complete understanding is also caused, insofar as complexity together with scarce (bounded) time and attention, or computational ability exist. Note that a strict causality theory does not include a role for random events or free will, although people may not be entirely predictable. Indeed, a diestic purist would

[35] Heisenberg (1927) demonstrated that "the more precisely the position of a particle is determined, the less precisely the momentum is known in this instant, and vice versa. One could know one or the other, but not both with complete accuracy. See http://www.thebigview.com/spacetime/uncertainty.html or Wikipedia for intuitive discussions of several uncertainty principles from physics. Heisenberg won the Nobel prize in 1932 largely for his uncertainty principle at the age of 31. After WWII, he was one of the founders of the Max Planck Institute for Physics. See also http://www.nobelprize.org/nobel_prizes/physics/laureates/1932/heisenberg-bio.html.

insist that a random event cannot exist, nor can a truly random number be generated.

A significant shift in methodological perspective takes place when we allow for probabilistic and other uncaused events. Less mechanical theories of the universe includes causal chains like those of the Diests, but also events for which there is not a one to one mapping from the past into the future. Einstein's lament was evidently the result of his frustration with quantum mechanics, which seemed to imply that the world includes not only phenomena that are not understood, but which are fundamentally random. In a world with numerous stochastic processes, many things "just happen;" they are not caused. Others may be said to be partly caused insofar as probabilities of occurence exist and are influenced by other phenomena.

Some of the processes generating stochastic natural or social events may be complex, just as some causal chains may be complex for more or less the same reasons. Others may be simple but have a very broad range of possibilities and produce events so slowly that few can be observed in a lifetime. Non-ergodic random generating processes are possible in which random events do not repeat themselves in a finite period of time. Such processes makes assigning probabilities to them difficult or impossible for finite lived beings such as humans. When such phenomena exist, unobserved possibilities continue to emerge, no matter how much experience one has with the event space or process of interest.

To suggest that some events are uncaused is not the same thing as claiming that free will exists. Free will requires humans or other beings to be create uncaused events. That is to say, at least a residual of human behavior must be uncaused. And, causal changes created as a consequence of choice, as opposed to random events within the body. One possibility is that a more or less random idea generating process is combined with a willful filtering of the results, which generates new behavior that initiates new causal chains. Such a process would qualify as free will, even if the choice settings imagined and focused on are themselves fully deterministic. Creative solutions imply that acts of genius are at least occasionally possible. When such new causes are introduced into either mechanical or probabilistic universes, new causal chains and conditional probabilities are produced.

Our own subjective experience implies that the latter happens more or less routinely. We build a new tower of blocks when two years old, we rise when we feel like it, even if prodded along by a parent, alarm clock, or cell phone. We make choices from menus at restaurants. We write a new computer program, develop a new theorem, write a new book, etc. etc. We also routinely learn from our mistakes. Acts of "genius" are commonplace in this sense, if major breakthroughs in theory or practice are not.

Free will in this classic, experiential sense, clearly requires uncaused events to be relatively commonplace.

Note that all of the above arguments--including the entirely mechanistic ones---imply that unmeasured uncertainty and surprise exist at the level of individuals and societies, whether causality is complete, all probabilities are fundamentally measurable, or not. Thus, whether one believes in free will, or not, complexity and/or finite information collecting and computing abilities are sufficient to produce surprises. For surprises to be relatively common phenomena, free will and/or relatively complex environments are sufficient.[36]

In this book the language of free choice will be combined with mathematical representations of optimization which imply that particular choices are in a sense "natural" given human nature and preferences. The author believes that the words placed on the pages of this manuscript are unpredictable--new--rather than simply the outcome of a complex completely causal chain, at the same time that he believes that--once imagined--most of the words that appear in the final draft have to be there to complete the argument.

The above suggests that phenomena can be conceptually divided into four rough categories: (i) causal and well-understood, (ii) stochastically well-behaved and well understood, (iii) poorly understood, although potentially belonging to categories (i) or (ii), and (iv) irreducibly uncertain because of the nature of the phenomena themselves and/or human creativity. The terms "Knightian uncertainty," surprise, and crisis refer to the last two categories. The more important these two categories are, the greater the role that surprises must play in any coherent theory of private and public choice.

A central claim of this book is that the last two categories are confronted on a sufficiently regular basis that a variety of systematic steps are taken to address problems associated with them.

Surprise as a Result of Intent

Great innovations and great catastrophes often are themselves a surprise and/or produce a wide range of responses to which change the course of economic and social life in unanticipated ways.

It bears noting that both innovation and catastrophe are often be products of intent. Innovations such as language, agriculture, trade, and metallurgy were partly intentional, as new sounds or symbols are linked to additional ideas, as new plants or animals are cultivated, as bargains involving different goods are reached, and as new minerals and methods for using them are developed. The overall result of a series of small innovations may itself be surprising. Doubtless the first farmers and metallurgists were not attempting to or expecting to reinvent human life, although they did. Lessor innovations may also surprise us and have similar, if smaller effects, on our own lives and on the world's economy, as might be said of indoor plumbing, central heating, cameras, video games, the color "off white," and smart phones.

Similarly, a major war, economic depression, or plague can have major effects on beliefs, plans, and economic development. Many of these effects are caused through intent coupled with causal chains. A bomb may destroy a particular bridge. The secondary consequences may also be predictable, insofar as the destruction of a bridge will increase transport costs. Many of the overall effects of

[36] This is, of course, one reason why geological and other historical studies are of interest. Such studies allow very long samples of physically recorded phenomena to be undertaken in a manner that is likely to be impossible to recreate in the laboratory. Such studies often reveal possibilities that will not be and have not been experienced in several lifetimes (the ice age), or by humanity itself (dinosaurs).

warfare may also be predictable such as their overall effects on prices, longevity, and birthrates.

Others are less so, as wars stimulate innovation and luck and conscious efforts to surprise the opposition play significant roles the course of wars. Other peaceful forms of rivalry also generate surprises for more or less the same reasons. New products, marketing strategies, or production methods, often produce greater advantages for firms and consumers than would simply producing more of familiar products in their conventional ways. In such cases, surprise is often an intentional consequence of some human decisions. An event does not have to be uncaused to be surprising.

Moreover, the same event may have different effects on different people. For example, the above innovations were blessings to some, although catastrophes to others. Buggy whip manufacturers and their employees doubtless regarded Henry Ford's Model T as a disaster. The term "computer" used to refer to persons with especially reliable computational skills who would do the arithmetic, calculus, etc. required to answer questions posed by other scientists, managers, or governments. Those highly skilled workers along with others who were skilled with logarithmic slide rule operations, were completely displaced through innovations in electrical-digital computers by IBM and Commodore, and Apple, and in hand held calculators by Hewett Packard, Casio, and Texas Instruments. Few of the current generation will even have seen a slice rule or know the origin of the term computer unless they are students of history.

Catastrophes arguably have lessor effects on human developments in the long run than innovations, but large, often surprising, losses of property and life on persons clearly have affects on plans and possibilities. The most common steps that private individuals and small groups may take are discussed in this chapter. The next two discuss how the risk of loss can be further reduced through various social organizations, including governments.

Planning for Unpleasant Surprises

That both pleasant and unpleasant surprises may be jointly generated by various combinations of potentially measurable and non-measureable processes has clear implications for planning. First, it suggests that truly ideal complete plans are impossible. Indeed the term surprise can defined by such planning failures, whether intentional or not. A surprise is any event for which one does not have an automatic, routine, response.

The possibility of such events will be taken into account by all planners, if they are truly forward looking. Perhaps the most obvious adaptation will be to reduce the scope and number of long term commitments. One should not bar and lock the door, if opportunity may knock or an escape from fire may be necessary. As the poet Burns once wrote, "The best-laid schemes o' mice an' men Gang aft agley." In settings where surprises are common place, the best permanent plans will fail nearly as often as a series of myopic responses.

This is not to say that all long term commitments will be avoided, but in areas of life in which surprises are commonplace, commitments that reduce one's ability to respond to surprises will be avoided. Moreover, plans that can be altered at relatively little cost will be favored. Such flexible plans allow one to adjust to unforeseen events to secure initially unrecognized gains and avoid initially unrecognized or improbable losses. Reducing long term commitments allows one to avoid losses and increase profits that might be obtained by revising one's plans. It bears noting that common law appears to acknowledge the importance of surprise events insofar as contracts can be breached for a variety of reasons including "acts of god" (major surprises) and, subject to damages, simply unexpected profit opportunities.

This is not to say that long term commitments never reduce risks. Efforts to self-insure often require long term commitments. One's rainy day funds may be accumulated over a lifetime, as might be said of efforts to accumulate stable relationships of reciprocity as with marriage, children in former times, and membership in other formal and informal insurance cooperatives. Even the accumulation of wealth for use as free reserves normally takes many years of disciplined savings and work. Advantages of free reserves over insurance for dealing with surprise events are discussed later in this chapter. However, it is to say that contracts will tend to be shorter term and less complete than perfect lifetime planning models imply.

For economists who neglect the existence of surprise events, such plans will appear to be suboptimal, although they are not for the actual circumstances confronted.

Atempting to Measure Unmeasured Uncertainty

In many cases, plans can also be improved by increasing one's understanding of the environment in which one operates. Knowledge is not always power, but it is often useful for planning purposes. To the extent that surprises can be reduced by acquiring information from others and from one's own research, more complete and effective plans are often possible.

In some cases, additional knowledge will transform unmeasured uncertainty into clear causal chains or conditional probability functions. In other cases, the domain of possible events may be better understood, even if the causation or probabilities behind them are not fully resolved. This might, for example, be said of contemporary efforts to understand earth quakes.

Modern tectonics suggests general locations where earthquakes are most common. Measurement of forces along trouble prone fault lines can predict the upper bound of the likely magnitude of the next quake. Once fault lines are determined, many will choose to depart for safer regions, while those that remain may build somewhat larger reserves and more earthquake resistant structures to mitigate earthquake risks, although significant earthquakes remain surprises when they actually occur. In this manner, earthquake research allows a better estimate of the requirements for emergency reserves and of the extent to which resistance to earthquakes should be incorporated into buildings and other structures. Similarly, in earthquake prone areas, simply looking at the structures that survive will provide information about builing design and locations that are relatively safe. For example, earthquakes in Japan implied that wood structures were safer than stone structures, in spite of their increased fire risks.

Such research does not often eliminate surprise, but rather reduces the number of surprise events and mitigates the losses associated with those events.

An Illustration of Planning "Failures"

The problems associated with sub-optimal (incomplete) plans can be illustrated in several ways. Table 1 characterizes a relatively simple choice setting that is sufficient to illustrate several of the problems associated with ignorance and sub-optimal partial plans. The person (planner) of interest can take four different actions (X = 1,2,3,4), and may confront three different states of the world ($Z=Z^0$, Z', Z").

Table 4.1
Planning without Complete Knowledge of Conditioning Variables

control variable / state	$Z = Z^0$	Z = Z'	Z = Z"
X = 1	2	2	-1
X = 2	3	-1	0
X = 3	1	3	-2
X =4	0	0	2

Suppose that the chooser, Al, has only experienced state Z^0 in his (or her) lifetime. In that case, Al will adopt X=2 as his strategy, because it maximizes payoffs in that state of the world. The payoff may be interpreted as utility, income, or likelihood of survival. As long as $Z = Z^0$, this choice is the best possible, and there are no problems associated with the fact that Al's strategy for life does not include full consideration of the other Z-states.

However, the state variable may unexpectedly change from Z^0 to Z'. The previous state of ignorance now causes problems. Not only does the standing strategy (X = 2) not work as well in the new state of the world, it produces net losses rather than net benefits that could be avoided with a different strategy--indeed the worst possible outcome.. Fishing from a rock in the center of a river may generate a lot of fish during normal times, but place one at great risk during an unusually high flood.

Al could clearly reduce his losses by changing his strategy--and depending on the magnitude of the losses, Al may need to adjust quickly. In such cases, a change from Z^0 to Z' may be said to have produced a crisis.

In the case illustrated, any change in plans or strategy will be an improvement, because the initial plans were not conceived with Z' in mind, and so they were less robust than they might have been. Indeed as noted, X=2, generates the worst possible outcome in the new circumstances (Z = Z'). Such planning failures are evidently sufficiently common in the real world that decisionmakers during a crisis are often encouraged to "just do something," (e.g make any change in existing plans).

However, not all changes are equally effective at advancing Al's interests. Strategy X=3 is now the best plan. If, however, future switches between state Z^0 an Z' are "anticipated," strategy X=1, has advantages. It performs well in both circumstances--it is a robust plan.

Crises and the Value of Information

Just as one's knowledge of possible events can be more or less complete, so can one's standing plans. As the extent of uncertainty decreases, the advantages of planning tend to increase. Moreover, as understanding of causal factors improves, plans can be devised that incorporate more complete and correct conditional responses to loss generating events. This does not happen without thought or planning, but requires analysis of how responses may moderate the losses associated with those events.

In many cases, a broad range of surprise events may have similar consequences. For example, severe storms, earthquakes, and terrorist attacks produce roughly similar medical emergencies and damage to capital goods (housing, factories, transport networks). Because responses to them can be similar, preplanning allows faster responses and reduces mistakes from panic and haste, as long as the rough outlines of the problems are correctly anticipated. Such plans do not require complete knowledge of all useful details of the crises that may be experienced, but require a recognition of common features.

Because each case, although similar in many respects, is also different in unique ways that were not fully anticipated, effective emergency plans necessarily include sufficient flexibility to be adjusted to the specifics of the problems at hand, which is often a non-trival task. The unavoidable errors made in adjusting to the problems at hand also have implications what should be done after a crisis is over.

A process of review is normally useful to make plans more general and flexible and thus more able to cope with a variety of unpleasant surprises. This may include more detailed plans, but will also necessarily include improved methods of revising those plans.

Neither the existence of a routine review process, nor of routine procedures to adjust preexisting "ideal" plans are implications of planning models that neglect the possibility of surprise.

Difficulty of Crisis Detection

After the fact, that a crisis occurred is usually completely obvious, as with an earthquake, large scale terrorist attack, or financial meltdown. Nonetheless, in the first stages of a crisis it is often difficult to distinguish between a few minor quakes, a odd hijacker, and an ordinary market adjustment from the larger events that can, if neglected, generate huge losses. In cases when such events can be detected before they reach their full "natural" magnitude, the losses associated with the surprise event can often be reduced.

A useful metaphor for such events is a rising river. Rivers rise after every rainfall, albeit with a lag as new water in the river's catchment basin flows towards the main path to lower ground and eventually to the ocean. If one observes only the water near the dock in one's home town, whether the river will rise a little or a lot cannot be known, until it happens. If however, the extent of the rainfall or snowmelt in the catchment basin is accurately measured, the rise in river level can be nearly perfectly predicted. Moreover, the rainfall, itself, tends to be somewhat predictable for a week or two before it actually rains. Such contributing factors, in principle, allow major river floods to be detected earlier as more complete data about the extent of rain fall and better estimates of likely rainfall are determined.

The earlier a reliable warning is obtained, the more steps that can be taken to reduce losses. People and property may be shifted to higher ground, temporary flood control structures can be erected, emergency supplies pre-positioned. In contrast, detecting a major flood after the river rises to unusual levels, as was the norm until the past century or two, reduces opportunities for limiting losses.

It bears noting that only reasonably accurate early warning systems are better than no early warning system. Mistaken forecasts produce losses by initiating costly steps at crisis management. Evacuating a city unnecessarily for a week to reduce losses from flooding or a major storm will reduce its annual economic output by about 2% and subject all involved in substantial inconvenience, expenses, as well as accidents. By wastefully consuming reserves and increasing skepticism about the need for future rapid responses, inaccurate early warning systems may exacerbate more crises than they moderate.

Accurate detection of crises, as early as can be done reliably, can greatly reduce losses. But accuracy is as important as the robustness of the responses undertaken.

An Illustration of the Effect of More Complete Knowledge on Planning

The value of surprise reducing research both before and after a crisis can improve plans, let us return to the illustration of table 4.1. Suppose that there is a scientific breakthrough that allows data on Z and the relationship between Z and the payoffs from X to be collected for the first time. Three related problems are generated by the discovery that Z is a conditional factor that changes through time.

First, there is the immediate problem. Previous private plans (or public policies) are now revealed to be suboptimal, or at least not to be robust or completely reliable. Second, the shift to better plans may not be possible because the effect of Z on the payoffs of X is only partially understood. Third, the future time path of Z and its effects on payoffs becomes a topic of research. After Z is noticed, the best strategy depends on the ease with which changes in Z can be observed or predicted. If it cannot be predicted, a minimax strategy may be the best that can be adopted. The effects of Z were clearly under investigated and resources (time and attention) may be shifted from other uses to the study of Z's effects. Additional data and analysis will be necessary to understand the future effects of Z on payoffs (income, health, probability of survival, etc.). Z, itself, may be caused by other factors or the stochastic process generating Z may have measurable or unmeasurable characteristics.

If Z simply moves to a new steady state, $Z = Z'$ and the new relationship between X and the payoffs are fully understood at that steady state, complete knowledge of Z may be unnecessary and $X = r(Z')$, and health reserve $E' = e(R', Z')$ may be adopted. Unfortunately, neither scientists nor policy makers can be sure that Z has simply moved to a new steady state without understanding the processes generating Z. Has Z temporally increased, moved to a new steady state, or begun a new process of increase? Perhaps Z is a stochastic variable. If so, how is the process generating it distributed? In this manner, a crisis and its associated revelations about one's ignorance may make one aware of previously unnoticed risks and uncertainties, and increase the demand for research on and analysis of associated phenomena.

Developing a better conditional plan based on the discovery of previously unknown causal or conditioning factors is a nontrivial matter. Discovery of previously unknown factors and strategies--breakthroughs--do occur, although not from the Baysesian calculus of mainstream models, for reasons discussed in the appendix.[37] Understanding what has changed and how to cope with it requires creativity--new strategies may have to be devised and previously unknown possibilities may have to be understood. Nor would it be immediately obvious that that a third state of the world, Z," is also possible.

In cases in which the link between the state variable(s) and relative effectiveness of alternative strategies is not obvious, some research about the path of the state variables and the effects of those conditioning factors on the effectiveness of the old strategies can be very helpful--indeed it may be a necessity.

Here one may note natural catastrophes have long affected locational and architectural decisions. Risks from hurricanes and other strong storms, floods, fire, and droughts can be reduced through locational choices: siting buildings away from ocean front and river flood plains, building them with stone, brick, or adobe somewhat away from other house, farming in places in which rain is commonplace, but not too commonplace, etc. And when risk free locations are not available, damages can be reduced through building and urban design--stronger, more fire and water proof walls and roofs, various cistern and drainage systems, building on stilts or sleeping on second floors.

Social catastrophes include war, mobs, crime, inflation, and deep recessions, are evidently more difficult to moderate than many natural ones, but people will attempt to reduce losses from these as well.

Mistaken Responses in a Crisis Setting

Given a need for quick adjustments and lack of knowledge (or plans) about the new circumstances, mistakes are likely during emergencies. Indeed, one reason for continuing old strategies is downside risk associated with blind adjustments to existing plans. That strategy X=2, has always worked in the past, may be regarded as a sufficient reason to continue using it, until more is known. Getting causality wrong, however, can lead ridiculous strategy choices being adopted.

Here, the reader might recall the wide range of public health problems that plagued mankind for most of human history. Many solutions were tried over many centuries and much analysis was undertaken, but truly successful policies were adopted only in the past century or so as knowledge of bacteria, viruses, and other hazardous materials improved. Few plagues threaten health in developed countries these days, but this is a fairly recent state of development.

Contemporary examples of such knowledge conundrums include urgent concerns over the future path of Islamic terrorism, global warming, financial crises,

[37] Bayesian updating requires all possibilities to have non-zero probabilities. If unknown probabilities have a "zero prior" than no updating via Bayes Law is possible. Additonal discussion of the limits of Bayesian models of learning are discussed in the appendix.

bond markets, and the acculturalization of recent immigrants within OECD countries.

Mistakes and Crisis Cascades

The ignorance and lack of planning associated with all true emergencies implies that mistakes are likely when policies are initially adjusted. Those mistakes may generate new crises insofar as the decisions made have unanticipated effects. In the model above, secondary crises might arise in the period in which the relationships between Y and the payoffs of X are not fully understood. For example, hasty scientific research, and policy analysis may mistakenly conclude that strategy 4 is the only safe strategy. But this will requiring subsisting on much less output than Al is used to, and in extreme cases may threaten his survival. Strategy 4 may dominate strategy 2 in the new circumstances, but may be at best a "stop gap," a policy that limits losses but fails to be sustainable.

Haste would not generate future policy problems without knowledge and planning problems, but such problems are essential features of the class of problems termed emergencies or crises. Rapid revision of plans without careful consideration of alternatives or consequences are more likely to produce mistakes than the slower more considered response of ordinary decision environments. As a consequence, ignorance and urgency may generate crisis cascades that are only indirectly caused by the original crisis . In an effort to avoid running over a rolling child's ball or careless cat, a driver may quickly shift traffic lanes and hit a truck. Some crises get out of hand simply because urgency prevents ignorance from being reduced sufficiently to permit accurate estimates of the (new) consequences of policy revisions.[38]

That such crisis cascades are not the normal state of the world, suggests that many of our "reflexes" work well in a broad range of emergencies and that routines for avoiding most such comedies of errors have gradually been worked out. Potential losses from crisis cascades are simply another general type of problem that needs to be taken into account when planning for a future in which unpleasant surprises are commonplace. "Look before you leap."

The Use of Emergency Reserves and Insurance

Perhaps the oldest method of dealing with unpleasant surprises that cannot be avoided through better planning is the accumulation of rainy day funds or free reserves. The accumulation of uncommitted resources that can be rapidly shifted to address a wide variety of problems (e.g. stem the losses) is an ancient technique for addressing major surprise events such as military attacks and unusual variations in annual crop yields. At the level of individuals persons may save for a rainy day, so that when bad luck arrives, they will have food, clothing, or cash to help them weather the storm. Similarly, at the level of a village, there may be food banks and military training to deal with short term crises (minute men).

Agricultural stockpiles can be tapped when annual supplies fall below some threshold. Free military reserves can be shifted from a more or less central location to the focal point of a major attack. Both systems have been used by organized

[38] See, for example, Viscusi (1997) who recounts and analyzes many cases in which a bit of new information induced panic and over reaction to crises.

societies from the dawn of recorded history, as in Egypt and China. In contemporary societies, families, large firms, and many governments hold rainy day funds in the form liquid assets such as currency, bank deposits, relatively safe government and industrial bonds, and lines of credit.

Note that the same reserves can be used for ordinary risk management and crisis management. If one knows the probability distribution of losses, one can self insure, as noted in the previous chapter. In this case the risk can be precisely managed by adjusting the size of the insurance fund. In the case of uninsurable risks, the same strategy can be used, although the loss generating process can not be described with a well understood probability function. In either case, the funds may be tapped out. In the former, by an unfortunate, but predictable, run of large losses. In the latter cases, by true surprises that exceeded the funds or other reserves put aside to weather the storm.

In either case, the existence of free reserves, of course, involves sacrifice in the periods that lack losses or crises. Nonetheless, in both cases, the fact that resources are held in reserve, rather than employed in some other way, allows a more rapid, and often less costly, response to a negative event. Without such reserves, resources would have to be drawn from other uses, which would produce other losses--indeed may exacerbate the losses borne. One may have borrow from others at very unfavorable terms or to sell assets at depressed prices. At the level of a village or town, the shift of police from "normal" duties to anti-terrorism or other emergency duties tends to cause ordinary crime rates to rise.[39]

On the Difference between Rainy Day Funds and Insurance

Emergency reserves or "rainy day" funds differ from conventional insurance and insurance funds in that they are created to address surprise events rather than specific well known events with well known probabilities. The problem of interest may be the result of intentional surprises, unmeasurable probabilities, or unmeasureded probabilities. The event space and its associated losses may not be fully understood, the sample size may be too small to accurately estimate payout rates, or the range of losses generated may be too large for robust funds to be accumulated. Such losses simply cannot be insured by durable profit maximizing organizations.

The difference between ordinary insurance and emergency funds can be illustrated by contrasting the problem of insuring events generated by a uniformly and a normally distributed loss generating process. Within a uniform distribution, complete insurance for any finite number of worse case outcome is possible, because the lowest payoff is bounded. In contrast, losses generated by a normal distribution includes the possibility of infinite losses and so reserves sufficient to handle all events are impossible. An insurance fund can be designed to cover 99% of such loss scenarios, but not all of them. Some uncertainties are unmeasurable, others are so large and rare that prudent insurance funds cannot be accumulated.

In cases in which losses can be very large, insurance companies normally insure damages *only up to a limit*, and often insure only a subset of the events previously experienced. For example, home insurance policies have a maximum payout and routinely exclude losses from floods and revolutions (where multiple,

[39] Research by Benson, Kim, Rasmussen, and Zhehlke (1992) and Klick and Taborrok (2004), for example, imply this will be the case.

large, simultaneous, claims are likely). Similarly, liability insurance normally is sold with a maximal payout for a single claim and maximal total for simultaneous claims.

Conventional insurance companies create insurance funds that are shared among subscribers for a price based on average payouts and their variation through time. For surprise events, such calculations are not possible. Prudent insurers recognize that they cannot accumulate sufficient funds to cover damages from all possible combinations of emergencies and/or sell such insurance at a reasonable cost.

It is for this reason that markets normally provide narrow forms of insurance with many restrictions rather than broad insurance without restrictions. Losses from wars, earthquakes, tsunamis, and major business cycles cannot be insured by firms in markets--and when a company promises to "do so," they normally become bankrupt when they are actually required to pay off the enormous claims associated with those events. That is to say, when insurance-like products exist for crises, the "insurance" companies providing them are doomed to failure, although they may experience profitable periods between such events.

Because insurance is not possible for major surprise events, prudence requires rainy day funds or emergency reserves. This technique cannot limit all losses, because extraordinary surprises are always possible. However, the limits of emergency funds are not determined by contract as with ordinary insurance, but by the size of the funds. [40]

Crisis and Evolution: Non-Rational and Rational Responses to Emergencies

Unpleasant surprises can be generated by both nature and man. In a subset of those cases, the losses generated by the new circumstances are existential ones that threaten survival. Not all unpleasant surprises are emergencies calling for immediate response, but longer term problems may also be existential and require significant revisions in day-to-day routines to survive, expand, and flourish. That every species faces such problems implies that in the long run only those that develop methods for addressing crises and longer term problems survive.

Evolution and Non-Rational Responses to Crises

Although most economic analysis (and environmental analysis) assumes that new problems are easy to recognize and solve, this is not the case for crises, which by definition emerge suddenly and demand rapid responses. In emergencies, there is not sufficient time to carefully work out solutions (e.g., determine consequences of all alternative actions and rank them in order to create a new or more complete plan or policy response function). This implies that crisis response tends to be

[40] In well developed markets, lines of credit may also serve as "free reserves." Such rights to borrow--up to a limit--are essentially similar to other asset backed sources of reserves that can be drawn down during emergencies.

more mistake prone than ordinary choices. Thus, intuition and luck, "good guesses," nearly always plays a significant role surviving major short-run crises.[41]

Insofar as luck is necessarily important, this implies that "trial and error" at the individual and community level are also important determinants of existing human routines for surviving emergencies. The responses that worked in the past, for whatever reason, will be passed on to other members of the community, places, and generations. Indeed a subset of such responses may become genetically hard-wired, insofar as those with them respond better and are more likely to survive than others. An example of such hard wired responses is the "freeze, fight or flight" response common among mammals. Other heuristics may be generated by combinations of genetic propensities and experience (Gigerenzer, 2008).

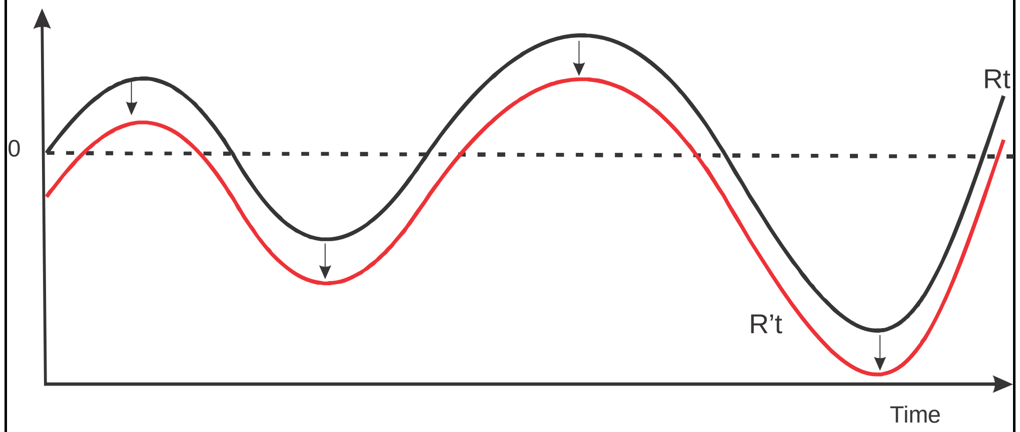
Evolution and Rational, Creative, Responses to Crises

That evolutionary pressures partially determine successful routines for responding to crises does not undermine the case for rational analysis of plans and policy alternatives, as is sometimes argued. Even a partial understanding of causality is often better than no understanding, because it makes detecting policy failures easier and faster and provides information about causal and effect that can be used to assess possible responses that have never been tried. Such partial theories tend to increase survival prospects by providing both more complete plans and a better foundation for "good guesses" during a short-run crisis. They also facilitate the identification of new circumstances in which plans can be improved before a crisis emerges.

In cases in which existential crises are long term rather than short term, observation, record keeping and analysis can help one detect what one's short term crisis intuitions and reflexes miss. A useful metaphor for such problems is the problem of growing seasons and rainfall. Rainfall varies from year to year in a more or less unpredictable pattern. As a consequence, to the extent possible, it makes sense to accumulate emergency reserves of food and seed to carry one through the occasional very bad season. What is hard to determine is whether the weather pattern has shifted permanently. Figure 4.1 illustrates the time pattern of changes to one's emergency reserves in such a setting. The top line is a more or less sustainable, in that the area under the curve in the good time (summer growing season) is equal to or perhaps a bit greater than that in the bad season (winter). A shift in weather patterns to the lower line requires an adjustment either in growing and saving routines or in location--or it will lead to disaster.

[41] These hypotheses can be tested. That errors are more common during crises suggests that the error terms associated with rational choice models will tend to be larger (heteroskadastic) during times of short run crises. If there are also more systematic mistakes (because of ignorance or constitutionalization of policy), dummy variables will also be statistically significant "explanatory" variables for such periods.

Figure 4.1: A Crisis Induced by a Change in Average Surpluses



(Note the smaller accumulation and greater depletion of reserves.)

Similarly, a series of floods that is more damaging than previously thought possible may cause potential flood risks to be reassessed and induce a shift in standing plans thought to minimize losses in the long run. When the dikes fail, it may be sensible to relocate the entire village or city. Similarly, a shift in climate that makes droughts more common, floods higher, or fires more fierce or frequent may call for an entirely new policies including both major capital projects and relocation. Dams or dikes may be constructed or expanded; living or farming flood zones may be discouraged; fire departments and building codes may be modified or created. masonry construction may replace wood; a great fire or defensive wall may be constructed around the community.

Many longer term crises can be thought of as instances in which a communities reserves and/or capital are reduced through time, by worse conditions than they had anticipated. When such shifts are unrecognized or not responded to with better plans (plans with greater average surpluses), a family, firm, or community my gradually disappear, as reserves and/or capital diminish beyond that required for survival in a world with random shocks and cycles, such as those induced by weather and the passing of seasons

In such cases, there is normally time for analysis and plan revision, for rational analysis. Communities that are able to plan and adjust to new circumstances will survive, while those that cannot do not.

Talent at Crisis Management and the Possibility of Experts

Crises tend to stimulate both rational analysis and creativity (xxxx). A good deal of the evolutionary advantage of complex nervous systems that can recognize and better respond to a broad range of crises and other existential threats. Superior crisis management, as suggested by Knight (xxxx, xx), may largely account for rationality. Nonetheless, persons and organizations vary in their ability and/or experience at crisis management. This not only provides an evolutionary advantage for recognizing good crisis managers, and for the use of institutions in which better crisis managers are given greater authority to direct crisis detection and/or responses during emergencies.

Because some persons are better at planning than others in a given action area, either because of talent, skill, or better knowledge of possible circumstances, deference to such persons can increase survival prospects. For example, children will defer to their parents who may defer to grand parents or experienced friends. In the contemporary environment, a retirement planner may plan for the parents, and an expert regulator or professor planning may suggest rules that guide financial planners.

Similarly, durable organizations will include routines that identify effective crisis managers and reward them with income and authority. Internal risks, unpleasant surprises, and crises will also be reduced by including succession plans for systematically replacing senior executives and other personnel critical to the organization's crisis management and innovation programs. Organizations will also set aside reserves and take out lines of credit to help them weather unexpected changes in revenues, costs, rivals, or taxes. In this manner, institutional designs, and specialization in risk and crisis management tend to emerge side by side with the risk bearing services analyzed by Knight in his chapters on market responses to uncertainty.

Entirely new professions, firms, and industries with expertise at crisis management will also tend to emerge and prosper.

Conclusions: Crisis Management as a Normal Activity

This chapter has argued that a significant part of a decision-maker's standing routines consists of efforts to reduce the frequency of, anticipate, and limit the losses associated with future unpleasant surprises. To ignore such efforts, is to ignore a large and significant part of life, and a large and significant part of what markets and government also cope with. Taking greater account of uncertainties does not simply add a blank unknown area of choice to one analysis, rather it forces one to think about the wide range of steps that will be taken in such cases.

This chapter suggests that (1) plans will be more flexible and less complete, (2) plans will include the use of larger uncommitted pools of reserves, (3) that retrospective analysis after a crisis will often find and correct more mistakes than implied by models that neglect the possibility of surprise, (4) many downside losses will be moderated with emergency reserves of various sorts, rather than complete insurance.

In general, the rational response to unpleasant surprises will be a series of standing routines for planning and revising plans that will be better cope with unexpected events than would be predicted by models that neglect the possibility of surprise.

Household Expenditures and Uncertainty Reduction

If both risks and crises are central elements of life, we should, and do, observe a wide variety of efforts to manage risk and crisis, not simply unsystematic deviations from the predictions of simple expected utility maximizing models. We should, for example, see greater resources invested in risk reducing strategies, insurance policies that limit what is covered, and standing free reserves. We should see organizations that include persons or units charged with planning for, detecting, and responding to unpleasant surprises. Plans will include fewer and weaker long term commitments than economic models predict. They will be regularly revised, rather than simply implemented. The optimal plan and optimal contract is less detailed and more "flexible," than the best plans for a world without surprise. Contracts. themselves, will not be fully binding.

Evidence that risk and crisis management are significant factors in contemporary life can be found in break downs of GNP statistics. Individuals spend much of their income on "necessities" (goods and services that reduce health and other risks) and insurance. For example, in the US in 2000, personal consumption expenditures were 6.8 trillion dollars. Of that, health care accounted for 1.1 trillion and insurance a mere 0.065 trillion dollars, about 1/6 of total consumption. Other necessities, for example, housing, food, and clothing accounted for 1.2 trillion, 0.54 trillion, and 0.25 trillion dollars respectively, another sixth of consumption expenditures.

If half of these expenditures can be considered as risk-reducing necessities, e.g. as attempts to moderate the effects of illness and bad weather, then more than a fourth of contemporary household expenditures are devoted to risk reducing consumption, health care, and insurance. (See table 677 of the 2012 *Statistical Abstract* of the United States.) Other household expenditures also includes both risk management and recreational aspects, as with expenditures on food services and accommodations, 0.41 trillion, education, 0.134 trillion, communication services, 0.08 trillion, and reading material, 0.05 trillion.[42]

Appendix to Chapter 4: Supplemental Ideas and Models

The simplicity of some stochastic processes can induce a state of mind in which we can imagine all things being understandable in statistical terms. However as the phenomena of interest become more complex, even if fundamentally similar, the difficult of teasing out the necessary relationships become far more difficult, as has for example proven the case in empirical economics, where nearly opposite hypotheses often have considerable empirical support.

The results of rolling dice and playing chess are largely independent of their circumstances. The distribution and relative frequency of a series roll is independent of past rolls, the surface upon it is rolled, the temperature, race or ideology of the roller, etc. A game of chess is fundamentally unchanged if it is played by Australian Bushmen, Roman Emperors, kings, or grammar school students. So relatively few conditioning variables need to understood to understand the distribution of outcomes generated.

That is not the case for all natural phenomena and rarely the case for social phenomena. At the very least, a wide range of conditional probabilities have to be understood to characterize the stochastic (or complex) processes that generate the outcomes of interest (daily temperatures or demand for life insurance). The extent to which risks can be reduced through better knowledge, risk pooling, and risk shifting devices depends on whether the process of interest is ergodic or not, that

[42] Of course as often pointed out, a life focused entirely on crisis management may itself undermine one's ability to cope with risks. Time off from lifes many crisis managing chores can refresh the mind and allow better future responses to both pleasant and unpleasant surprises. Recreation accounts for 0.64 trillion, about ten percent of household consumption.

is to say whether a process generates repetitive outcomes, or not. If some of the processes is entirely non-ergodic, then new events will constantly be generated, and people would constantly be face unanticipated and unplanned for events.

In choice settings where uncertainty is potentially measurable, ignorance and planning limits imply that we all will at least occasionally confront unpleasant surprises for which no predetermined responses exist. At such points, our plans may need to be revised--and revised rather quickly to avoid loses that we did not previously take full account of.[43]

Differences Between Bayesian Learning and Reduction of Ignorance

The most widely used method of incorporating imperfect information into rational choice models assumes that the basic information problem has to do with poor estimates of frequency distributions. The poor estimates in question are normally assumed to be produced by small samples rather than failures to recognize or know conditioning variables. This allows the poor estimates to be corrected by simply increasing sample size. The most famous applications of this approach are the various search models of market prices (Stigler xxxx) and unemployment (xxxx xxxx) and the various game theoretic implementations of Bayseian subgame perfect equlibria (xxxx, xxxx).

The ignorance representation is less widely used, in part because it is less consistent with some modern characterizations of "rationality" and in part because it appears to be a less systematic and mathematically elegant way of representing the nature of imperfect information. However, both these objections essentially require the absence of surprise, or at least that surprises are relatively unimportant factors in life or in contests, assumptions that we have challenged in chapter 2.

For the purpose of crisis management, the search or Baysian approach have two problems. The search and Bayesian representations of imperfect information, but not complete surprises. Complete surprise is impossible, because there are no "unknown" possibilities. Moreover, the usual Bayesian characterizations of information allows the possibility of mistakes, but not systematic error in the long run. In the long run, everything becomes known as samples (experience) increase to infinity. The later ignores the finiteness of life and the fact that it is impossible to perfectly transfer knowledge across generations. The former is a convenient modeling assumption, but may lead one astray when investigating settings in which surprises and emergencies are possible.

That is to say, in a setting in which natural ignorance exists, two sorts of learning are possible. First, one may gain precision in one's assessments of settings one is already familiar with--e.g. more precise estimates of Xt in the illustration. Second, one may learn about new previously unknown possibilities. For example,

[43] It bears keeping in mind that most empirical estimates of micro-economic models have R-squares of half or less. This implies both that the choice settings confronted by individuals and organizations are only partly predictable. This unpredictability may be a consequence of the broad range of unanticipated surprises that consumers confront, both good and bad. These cause plans to be adjusted through time in response to them. Moreover, the errors in static models can be generated from such behavior even if the adjustments are perfect, but also if some adjustments are mistakes that are later corrected, as suggested above.

variable D might not initially have been known and could be discovered in the course of experience or analysis. Similarly, Alle might not have known that decision node 3 exists or that choice R could ever therefore be sensible. Moreover, choice R itself may not have been known. The first sort of learning can be modeled using the conventional statistical (Bayesian) models of learning. The second cannot be so readily modeled, which is one reason why reductions in ignorance (and innovation) tends to be neglected in most economic analysis. Eliminating ignorance involves a quite different process of learning than increased statistical sampling does.

Recall that the posterior probability of event s, given that m has occurred, is the probability of s times the probability of observing m, given that s is true, divided by the probability of event m.

$$P(s|m) = [P(s)\ F(m|s)/\ F(m)\ ]$$

If the probability of s is initially assigned a value of zero, $P(s) = 0$, whether implicitly or explicitly, the posterior probability will always be zero whatever the actual probabilities of m and m given s may be. This holds regardless whether P(s) is assumed to be zero or if one is totally ignorant of the existence of s and so no probability is assigned to s. That is to say, Bayesian updating allows refinements of theories (which can generally be represented as conditional probability functions) over events that are known to be possible, but not over events completely ignored or completely ruled out a priori.

Learning these "missing dimensions" involves a reduction in ignorance that is fundamentally different from Bayesian updating and similar statistical representations of learning. Priors are not updated when ignorance is reduced, but, rather, new priors are created for previously unrecognized possibilities.[44] The assumption that persons are ignorant of relevant conditioning variables implies that unknowns are associated with every decision, and that mistakes are made more or less routinely. "Unbiased" estimates and perfect decision making is impossible unless ignorance does not cause biased estimates of future events or probabilities of those events. In areas in which missing variables are important, rational decision makers make systematic errors because they are ignorant of relevant variables and relationships.

Here it bears noting that scientific progress in the usual sense of the word implies that ignorance is being reduced, e.g. breakthroughs are occurring, not simply that priors over known phenomena and relationships are being adjusted. The caveman did not know what a helicopter was; nor could he have explained

[44] Binmore (1992, p. 488) suggests that a complete list of the possible outcomes is not even conceptually possible or at least is beyond the capacity of real decision makers. Frydman (1982) argues that agents cannot generally compute optimal forecasts in competitive markets, because they cannot estimate the forecasts of all other agents.
Cyert and DeGroot (1974) provide one of the earliest analyses of the relationship between Bayesian learning functions and rational expectations. Cyert and DeGroot note many cases in which Bayesian learning converges toward rational expectations and market clearing prices. However, they also note several failures (inconsistencies) in cases where the original model used by individuals (firms) is incorrect.

how fiber optic cables operated or, for that matter, why the sun rose each morning.

Ignorance, nonetheless, does not rule out rational behavior. Rational choices remain possible in the sense that all the information available to decision makers is taken into account and the best of all known possibilities is chosen.[45] Ignorance simply implies that the list of possibilities considered may be very incomplete and that an individual's understanding of causal relationships (the conditional probability distributions between current actions and future events) may be erroneous in many respects.

Together, these imply that systematic mistakes can be made and surprises experienced by even the most careful and forward-looking decision makers. The farmers of 4,000 BCE did the best that they could, given their theories, but did not manage their fields in the most effective way possible. Nor, were they irrational when they adopted plans based on ignorance of the weather or flood levels of the rivers near where they farmed (nor presumably are today's farmers when they make similar errors). Such decisions might be said to be instances of "bounded rationality" in the sense that they are informationally bounded. However, they are not necessarily "bounded" because of lack of computational power or systematic failures of the mind, as is sometimes implied by the researchers who employ the bounded rationality concept (Conlisk 1996), but rather because so much is unknown to decision makers at the moment that choices and plans are made.

Optimization with Missing Conditioning Variables

The model developed in the chapter was done in a discrete table in order to minimize mathetical distractions for readers. However, for those concerned with the “discreteness” and discontinuities of the illustration, an illustration in a more tractible (continuous and differentiable) environment is developed below. The conconclusions are very similar to those generated from the model in table 4.1.

Suppose that individuals maximize a strictly concave utility function defined over their own private consumption, C, and personal health, H,

$$U = u(C, H) \tag{1}$$

Suppose that an individual's health, H, is a random variable that is affected by his or her own private expenditures on health care, E, and other costly personal (or governmental) decisions that reduce known health risk, R. Healthcare expenditures are undertaken only in the case of illness, and so can be regarded as an instance of self-insurance. In addition to these two known control variables, suppose that an individual's health is also affected by risk factor Z.

R, E, and Z are in most cases long vector of known, unknown, and neglected variables, but for the purposes of the model, each is treated as a single variable.

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[45] The quality of individual decision making may also be affected by intense emotions, such as fear or anger, that reduce the quality of rational decision making, but these effects are neglected in the present analysis.

And, only Z is assumed to be unknown (or unobserved) to the individual making the choice being modeled. Each combination of E, R, and Z creates a (conditional) probability function for health states.

$$f(H) = h(H \mid E, R, Z) \qquad (2)$$

Personal income Y is assumed to decline as steps to control known health risks are taken (avoiding contested lands, consuming fresh foods, drinking only clear water, personal hygiene, exercise, etc.).[46] A similar reduction would occur if the risk reducing rules were adopted and enforced through governmental regulations or conditional taxes, but analysis of such policies is postponed until part II. An individual's personal opportunity set for private consumption and health care in this case can be written as C = Y(R) - E.

Assume further that individuals maximize expected (average) utility and so select their risk reducing efforts and health-care expenditures to maximize,[47]

$$U^e = \int h(H|E,R,Z)u(Y(R)-E,H)dH. \qquad (3)$$

Differentiating equation 3 with respect to E and setting the result equal to zero allows the expected utility-maximizing level of health-care reserves for a given level of care, *R*, to be characterized as:

$$\int [h_E U - hU_c]dH = 0 \qquad (4a)$$

Equation 4 in conjunction with the implicit function theorem implies that the private demand (conditional plans) for health care can be written as

$$E^* = e(R, Z) \qquad (5.0)$$

with

$$E^*_R = \left(\frac{\int [h_{ER}U + h_E U_c Y_R - hU_{cc}Y_R]dH}{-[U^e_{EE}]} \right) < 0 \qquad (5.1)$$

$$E^*_Z = \left(\frac{\int [h_{EZ}U]dH}{-[U^e_{EE}]} \right) > 0 \qquad (5.2)$$

with $U^e_{EE} = \int [h_{EE}U - 2h_E U_c + hU_{cc}Y_R]dH < 0$

46 Across some range, personal income may increase as R increases, insofar as improved health improves productivity in the workforce. However, when R is set at approximately the level that maximizes utility, R will be increased until it is in the range in which R decreases personal income (see below); thus, for expositional and analytical convenience, Y_R is assumed to be less than zero across the range of interest.

47 Sufficient conditions for strict concavity are $U_C > 0$, $U_H > 0$, $U_{HC} > 0$, $U_{CC} < 0$ and $U_{HH} < 0$. In addition to the strict concavity of U, it is assumed that the marginal return from private health care is reduced by effective regulations, $H_{ER} < 0$, and increased by risk factor Z, $H_{EZ} > 0$.

As individuals take more precautions, they put aside less for health-care reserves. As risk increase because of unknown shocks, once those new risks are recognized, reserves will be increased.

In cases in which both the level of care and health care reserves are determined simultaneously, equation 3 should be differentiated by both R and H, the results set equal to zero. Together with implicit function theorem, equation 7 implies that both the level of care and the health-care reserves are implicitly determined by variable Z, because Z determines where the expected marginal benefits of risk reducing behavior and health-care reserves equal their expected marginal costs:

$$E^* = e(Z) \tag{8a}$$

$$R^* = r(Z) \tag{8b}$$

The individuals of interest, however, are assumed to be ignorant about risk factor Z, so function r(Z) cannot directly determine and individual's either risk reducing behavior or health care expenditures. It does so indirectly by determing the probability function of health states, as understood by the individuals in question.

Z has direct effects on the marginal returns to health expenditures, H_E and risk reduction, H_R. As long as Z remains at a steady state, $Z = Z^o$, These returns may be known with certainty. In such cases, $E^* = e(Z^o)$ and $R^* = r(Z^o)$ can be adopted without any knowledge of Z.

Only in such cases, does ignorance of Z fail to reduce the effectiveness of private or public plans.

Effect of Discoveries

Ignorance of Z, however, can be a significant problem that leads to systematic errors in both public and private decision making if Z is not completely stable. For example, suppose that Z increases from Zo to Z' and produces an unobserved increase in the marginal returns from government policies to reduce health risks and to private risk reducing expenditures. Such changes might go unnoticed if data on H_E and H_R are collected infrequently or if small changes are neglected. H is stochastic and thus minor fluctuations in the effectiveness of risk reducing policies may be discounted as unexplainable random effects.

As long as the changes generated by the new level of Z are not recognized, the original policy remains "optimal" given the information available to decision makers, but no longer best advances their true interests. The unnoticed change in Z implies that equations 4 and 8 are no longer be satisfied at $R^0 = r(Z^0)$ and $E^0 = e(R^*, Z^0)$. Losses accumulate, but there is no crisis because no attention is focused on policy reform. People are less healthy and/or comfortable than they would have been with more complete information, but they do not yet realize this.

The rate at which unnoticed losses accumulate under the individual's standing choices (strategies or policies) is:

$$\Delta U^e = \int h(H|E^0, R^0, Z)u(Y(R^0) - E^0, H) - (H|E', R', Z)u(Y(R') - E', H)dH \tag{9}$$

where $R^0 = r(Z^o)$, $E^0 = e(Z^o)$, $R' = r(Z')$, *and* $E' = e(Z')$.

The urgency of the need to adopt plans that account for Z varies with the magnitude of the losses that accumulate under new values of Z. The higher the rate of perceived losses, the greater is the urgency. In many cases, the losses are so great that they are life threatening. In others, the losses are minor, and little urgency exists.[48]

Can Crises Be Anticipated?

Many other cases fall between these extremes. Some outcomes can be potentially controlled, yet present knowledge may be insufficient to do so. The results of efforts to do so might appear to be effective or ineffective. For example, Praying for the sun to rise tomorrow, might always be associated with sunrise the following day, without actually affecting the sun rise itself. Praying for better weather next year, would not for individuals and groups to take steps to increase average returns, reduce downside risks, or cope with the unpleasant surprises as yet unaccounted for.

A Suggested Shift in Focus From the Standard Neoclassical Approach

Social science tends to focus on the parts of life in which our routines work well, because these areas of life are easiest to understand. An economist would, for example, predict that in ordinary times, people save and spend a more or less constant fraction of their income and purchase a more or less constant--equilibrium--amount of clothing, food, and transport services. Changes in one set of familiar circumstances to others, will cause routines to shift in a more or less predictable manner. An increase in gasoline prices relative to income will tend to cause persons to adjust their routines in a manner that reduces gasoline consumption. Less driving may occur, smaller cars may be purchased, and more mass transit and bicycles may be used.

Such models and their associated theoretical structures indirectly suggest that risk is a bit of froth about an essentially predictable process that can account for most behavior. However, most empirical work in microeconomics suggests that such models can account for only about half of the variation in prices, outputs, etc.. The unexplained residual implies that persons using conventional models will confront both risks and uncertainties, when making plans for the future. It also suggests that a significant portion of what drives decisions is missing from the models.

Although, many issues can be clarified by ignoring risk and focusing on stable equilibria, the importance of risk and uncertainty on private and public choices is obviously neglected by such analyses.

However, if exogenous shocks (surprises) occur more or less regularly, but not predictably, they will also affect the manner in which people make decisions and behave. For example, decision makers will be less confident of the

[48] Urgency may exaggerated in cases in which panic or terror is generated by the sudden changes in perceived health risks associated with disease or attacks. In effect, Z' may be mistaken for Z'', with Z'' >> Z, or relationship $H_Z < 0$ may be misestimated because of the scarcity of information about current and past values of Z.

completeness and optimality of their plans than the mainstream models imply. As a consequence, they will tend to adopt more flexible plans, ones that can adjusted at various margins than the standard rational choice models suggest. They will also be looking to improve their plans, a task which is impossible in the standard models. And, as developed in Chapter 3, they are likely to maintain reserves or unused lines of credit, rather than allocate all of their resources as normally assumed. These aspects of choices under uncertainty may not be very important for some decision settings, but in others they will be the main consequences of the choices made.