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Abstract This paper provides a rational choice-based analysis of the causes and consequences of surprise events. The paper argues that ignorance may be rational, but nonetheless produce systematic mistakes, inconsistent behavior, and both pleasant and unpleasant surprises. If ignorance and unpleasant surprises are commonplace and relevant for individual and group decisionmaking, we should observe standing institutions for dealing with them – and we do. Insofar as surprises are consistent with rational choice models, but left outside most models, it can be argued that these methodological choices mistakenly limit the scope of rational choice-based research.

Keywords Ignorance, Rational Ignorance, Natural Ignorance, Bounded Rationality, Rational Choice, Biased Expectations, Crisis Management, Social Insurance, Bailouts, Economics of Information

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I. Introduction

The world is not always, or perhaps even usually, fully predictable, but some unpredictable events, such as coin tosses, have patterns that are relatively easy to recognize. Such patterns may be described probabilistically once the range of events and their relative frequency are understood. Others may not lend themselves to such descriptions, because neither the range nor frequency of events are well understood (or perhaps even understandable).

In cases in which the range and frequency of a class of unpredictable events are well understood, a variety of steps can be used to cope with them. Individuals might, for example, maximize average returns, rather than actual returns, and simply accept the fact that returns will vary from the "expected" value for reasons not fully understood. In cases in which actions can be chosen after a random event takes place, one might plan for every possible contingency, and once a particular event is observed, the best response to that possibility can immediately be put into action. One may pack for a trip to the beach, and pull out a sweater when the evening temperature falls to 15°C (60°F) and pull out the umbrella and raincoat when it begins to rain.

For unpredictable events with ranges and frequencies that are not completely understood, similar but not equivalent steps, can be taken. It is, for example, possible to maximize average "subjective" returns based on intuitive assessments of the relative frequency of possible events, even when only a subset of the actual possibilities are known. It is also possible to form contingent plans based on the possibilities of which one is aware. However, if the range and connections among events are not completely understood, subjective estimates of probabilities will not be accurate and it will not be possible to have a conditional plan that accounts for every event that may occur. One may pack a sweater and umbrella for a trip to the beach, but have no idea about what to do when the tsunami alarm goes off. Indeed, one may not even understand the meaning of a tsunami siren, or warning announcement in Japanese, even if one hears the siren and warning and knows what a tsunami is.

This paper attempts to develop a framework for analyzing decisionmaking in settings in which ignorance affects expectations, plans, and actions. The analysis is grounded in rational decisionmaking models, but focuses on a somewhat neglected informational problem, that of ignorance. A variety of informational problems and their consequences are routinely analyzed by economists, but both rational and natural ignorance tend to be ignored. Yet, problems associated with ignorance are sufficiently commonplace in real life that people devise private and public routines for addressing them. Many of these attempt to reduce the downside risks of unpleasant surprises.

The first part of this paper provides a rational choice explanation for ignorance grounded in information costs and explores a few implications that are relevant for economic theory. Ignorance limits possibilities for unbiased estimates and implies that mistakes and surprise are possible. All three of these possibilities are neglected in most rational choice models. The second part of the paper suggests that people may learn from mistakes associated with ignorance, but not in the manner proscribed by Bayesian learning functions. How ignorance is reduced is a nontrivial methodological issue, although we know it to be possible. The third part of the paper analyzes how people cope with mistakes and surprise events. Once the possibilities of mistakes, surprises, and crises are recognized, systematic steps will be taken to attempt to reduce losses from them, although these steps will necessarily be less than perfect.

The choice settings of interest for this paper are those Frank Knight (1921) referred to as involving uncertainty. Knight argued that managing downside risk for well-understood probabilistic events is possible through prepaid (ex ante) insurance programs. He went on to suggest that insurance markets were not always possible, because of uncertainty, and so economic profits – and presumably losses – were possible in competitive markets. The problems addressed in this paper have also been analyzed by Shackle many times (1969, 2010), although from a different methodological perspective. Among contemporary game theorists, Binmore's work on "large worlds" (2011) is most similar to the perspective developed below. In a world in which ignorance is important, one cannot often 'look before one leaps'. Knight focused much of his attention on profits; this paper focuses mostly on losses. Managing downside risks in settings where unpleasant surprises are commonplace is difficult.

For most of the purposes of this paper, it is sufficient to focus on how decisions about data collection can affect expectations, choices, and consequences. Problem associated with costly data collection imply that systematic mistakes, surprises, and crises (emergencies) are possible for forward-looking consistent decisionmakers. Similar conclusions could also be reached by assuming that the "data" are perfect and complete, but that processing time is divided among observations in various ways, or biased because of faulty mental models, systematic computing errors, or self-delusion. These informational processing problems are real, but are not necessary to produce the problems focused on in this paper. For most of this paper, it is assumed that the information collected is used as well as possible.[1] An exception is the section on crisis management in which problems of surprise are likely to be magnified by calculation errors associated with rapid decisionmaking.

II. Ignorance and Mistakes as Consequences of Information Costs

A good deal of information is free. One gets it as part of ordinary activities without making any special effort to obtain it. Some of that information is about relatively simple natural processes, and so it takes relatively little effort to turn it into knowledge about the world that can be used in one's day-to-day planning and decisionmaking. A switch on the wall determines whether a light is on or not, and once this is understood, the switch can be turned on to provide additional light when it is darker than optimal for the activities at hand. Other information requires significant investments of time, attention, and money to acquire and transform into useful knowledge. A good deal of information only partly describes complex phenomena for which causal connections are multidimensional. In any area where several factors (A, B, C, D, E, etc.) jointly determine variables of interest (X, Y, and Z), mastering the details may take considerable time, attention, and money. In cases in which the conclusions reached are used to rank alternative actions (H, I, and J), it is clear that mistakes are possible, especially when the relationships of interest are difficult to understand and to calibrate once understood.

For example, most economists and policy analysts spend many years mastering specialized modes of reasoning and becoming familiar with various statistical measures of economic activity in narrow subfields of economic policy. In such cases, information is not free and individuals and organizations will naturally optimize with respect to collecting and processing it in a variety of ways, including the hiring of "expert" economists.

[1] Only honest mistakes in data collection and analysis are discussed in this paper. Feigenbaum and Levy (1996) discuss how preferences over estimates may affect scientific work.

A. An Illustration: estimating the value of a determinant process with partial data

Individuals and group plans are often conditioned on the values of physical or social phenomena, because such phenomena partly determine the consequences of individual and group decisions. For farmers and their communities, the last day of frost or high water mark of a nearby river in the current year will affect what is produced from a given crop and planting date. For a tourist, the expected temperature and rainfall will affect what clothing to bring, and the actual temperature and rainfall will affect what is worn and which sites will be most enjoyable to visit in a given country on a given day. For an investment house, investment strategies vary with estimates of risk-free long-term interest rates and market volatility. For an environmental agency, the extent to which the average temperature of the earth is affected by future natural and social processes will affect its recommendations on a broad range of microeconomic and macroeconomic policies.

There are a nearly endless range of physical and social phenomena on which people base their plans and policies, because these determine the consequences and rewards of the actions specified by those plans and policies.

For the purposes of illustration, consider a series of decisions by Alle, who makes informational, planning, and action choices. Assume that the variable of interest, X (perhaps the last frost date), is determined by four other variables, A, B, C, and D (perhaps length of day, average cloud cover, average wind direction, and latitude). Suppose further that the causal relationship is a simple linear one (which would probably not be the case for the last day of frost) and can be written as:

$$X_t = aA_t + bB_t + cC_t + dD_t, \qquad (1)$$

where a, b, c, and d are constants and A_t, B_t, C_t, and D_t are the values of A, B, C, and D at time t. Suppose that, given the values of A, B, C, and D in year t, one can predict X_t perfectly.

Assume X_t is for some reason impossible for Alle to observe directly at the time that knowing X would be useful for planning purposes, or at least is more difficult to observe than the other variables, and so is normally estimated from a model of some kind. X_t might, for example, be observable only after the event, as with the last frost date in the growing season of interest. Suppose that the values of A, B, C, and D, are generated by time-independent processes and that the processes for A, B, and D, can be represented as three uniform random processes with mean 0. Variable C, for some reason, is generated by a different process, and has for some time taken a constant (steady state) value, with $C_t = C_{t-1} = 0$. (These simplifying assumptions help remind us that real-world phenomena are normally much more complicated and more difficult to know than we often assume for the purposes of building tractable models – which is, paradoxically, what makes models useful.)

Together, these assumptions imply that the unconditional expected value of X is zero, but that the conditional expected value at time t differs from zero according to the values of A, B, and D at time t. Because plans (strategic choices) at time t can be improved by knowing X_t, it may be worth collecting past information about A, B, C, and D, so that a, b, c, and d can be estimated. Given those estimates, information about A_t, B_t, C_t, and D_t would also be useful, so that precise estimates about X_t can be made and more profitable decisions made at time *t.*

How much data and what kind of data Alle will gather depends on both information costs and the expected improvement in outcomes generated by knowing X_t. Suppose that data on A are cheaper to collect than data on B, which are cheaper to collect than data on C, which are cheaper to collect than data on D. This presents Alle with an informational choice concerning the amounts of each type of data to collect. I have argued elsewhere (Congleton 2001, 2005, 2007) that the corner solutions at which no information is gathered about a subset of the variables is the proper meaning of rational ignorance. Such corner solutions are clearly possible solutions to Alle's informational choice.

To illustrate the difference between general (unconditional) and specific (conditional) estimates, it is sufficient to consider cases in which the values of A, B, C, and D differ from zero. For example, if they take the value 1 at time t, the true value of X_t will be $X_t = a+b+c+d$, which clearly differs from zero. Zero in this case is a biased estimate, given the information about A, B, C, and D that is potentially available. Smaller degrees of (conditional) bias may occur when only partial information about the values at t is collected, although not in all cases. For example, in the above case, if only information about A and B are collected, the value of X is predicted (estimated) to be a+ b. Bias falls if a+b is closer to a+b+c+d than zero is. This would be the case if all a, b, c, and d > 0. However, bias may actually increase if a+b > 0 and c+d <0. In such cases, as the saying goes, "a little information may be a dangerous thing."

Note that this illustration demonstrates several points that are relevant for thinking about rational choice in settings with high information costs. First, there is a difference between conditional and unconditional estimation. A phenomenon may have a well-behaved and easily computed expected value for unconditional forecasts – here 0 – without making the phenomenon of interest easy to predict in the conditions at hand. Second, time-relevant estimates often require specific information, as well as good estimates of the causal connections among variables. To estimate X_t requires values for a, b, c, and d, and also data for A_t, B_t, C_t, and D_t. Third, ignorance of any of the relevant parameters or variables at time t implies that estimates will be biased at time t. One cannot be simultaneously rationally (or naturally) ignorant and have rational expectations unless the neglected variables are all irrelevant for the estimate at hand. An unbiased forecast cannot be made without timely and relatively complete information (observations about all relevant variables).

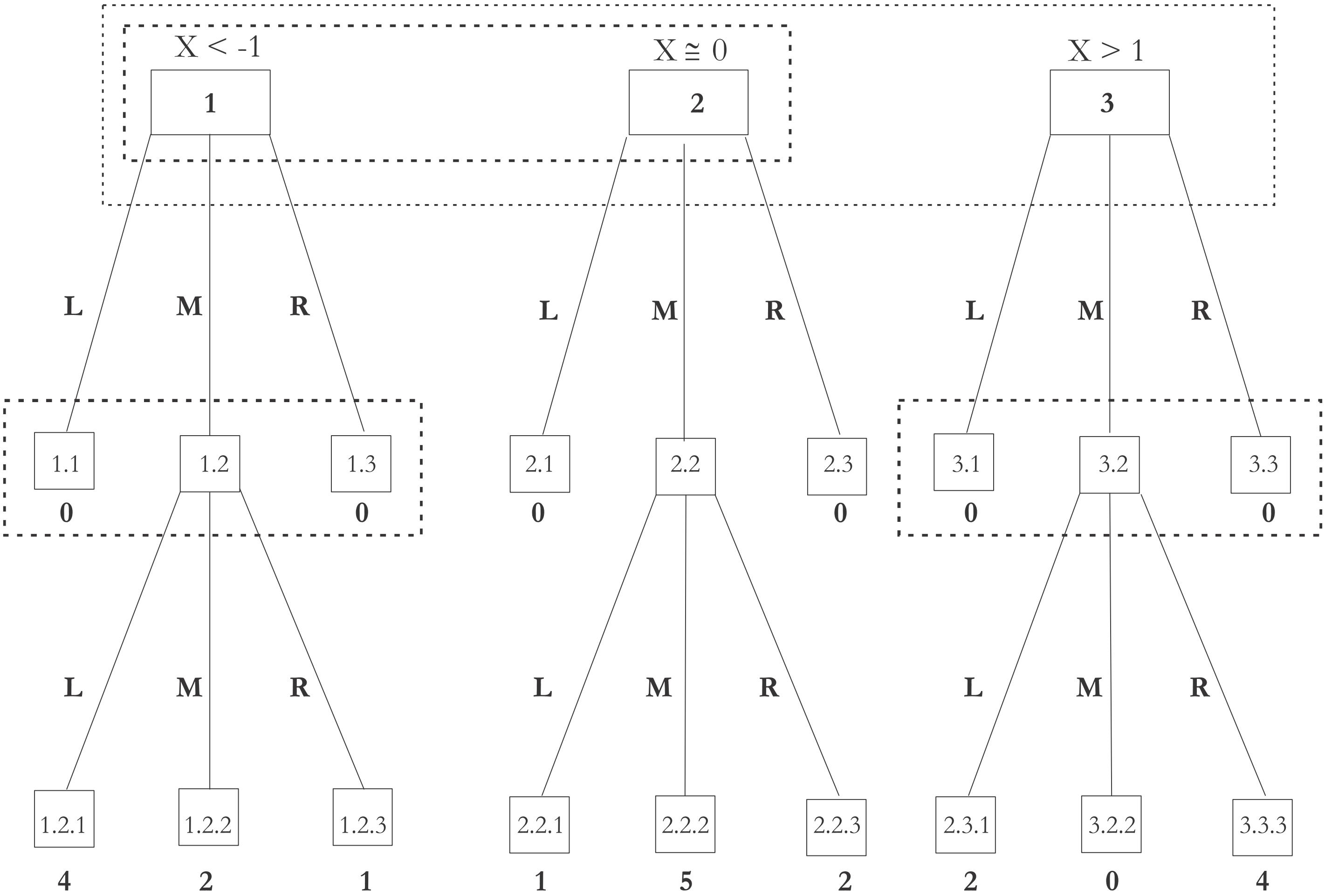
B. Mistakes: Choosing Plans with Less than Perfect Estimates

The previous section demonstrates that that rationality, in the sense of unbiased expectations, may not be possible when information costs are significant and causal chains are complex. We next examine how Alle's choices may be affected by the use of such imperfect estimates.

Figure 1 (below) can be used to illustrate several kinds of mistakes that might be associated with Alle's estimates of the value of X_t. Figure 1 characterizes a game against nature in which a sequence of choices must be made and the best plan depends partly on an accurate assessment of the initial circumstances. The initial decision node (1, 2, or 3) is determined by the value of X_t. As noted above, X_t may be, for example, the number of days with temperatures below 0°C (32°F) during the growing season in year t, the high water mark for the season, Alle's ability or mastery of three subareas of economics, or the present and future states of an organization's internal job market. The payoffs might, for example, represent profit associated with Alle's crop production in an area that is prone to frost or flooding, grades from a sequence of courses in economics, or income produced by career choices within a particular large organization.

The first "rational step" is assumed to be "obvious;" it is not affected by the value of X and the associated initial decision node. However, the best next step depends on which de-

Figure 1
Making Decisions When Circumstances Are Not Clear



cision tree (subgame) Alle is really on (in). In the case of interest, the value of X_t is determined by exogenous factors (nature), but in other similar choice settings, it could be a consequence of deliberate choices made by others in the contest of interest. There are many choice settings in which the value of some variable (or vector) X_t determines which decision tree (subgame) one is actually on.

In "normal" times, X takes values clustered around zero and the second node with its associated decision tree is the one most often faced. (A weighted sum of independent uniformly distributed random variables is normally distributed.) However, circumstances are not always typical, so Alle may or may not be at node 2.

It is interesting to note that Alle's choice of methodology influences her decision when she remains rationally ignorant about X. For example, if she decided to collect no information about A, B, C, and D (or X) and has chosen M in stage 1, Alle does not know whether she is at node 1.2, 2.2, or 3.2. If she uses the Bayesian approach (with diffuse priors), she will be indifferent among second-stage choices, because the expected value of each second-stage strategy is 7/3. If she is a maxi-min player, she will prefer the L and R strategies in the second stage to M. If she is an expected value player (as many economic models assume and policy analysts appear to be), she will assume that she is initially at decision node 2 and adopt the middle course of strategy at both the first and second decision point.

The difference between the realized payoff and the payoff potentially available with perfect information is one meaning of "mistake." It is clear that mistakes in this sense can be made under all three methodologies, according to the true value of X_t, and thus the best plan from the initial starting point. It is also possible that one of the methodologies on average yields results that Alle finds more pleasing than she does other results, but does not know this beforehand. As time passes, she may also come to believe that she has been using the wrong methodology. Higher-level mistakes are often more persistent than wrong decisions at an instant in time, because evaluating their relative merits requires more information than many lower-level decisions. It is often difficult to evaluate alternative methodologies without detailed knowledge of the circumstances in which they are to be employed. Nonetheless, all these methods are sensible ways of coping with acknowledged ignorance.

Of course, knowing the possibility of mistaken choices, Alle may invest in information about A, B, C, and D in order to reduce her uncertainty about which node is actually her starting point. A better estimate of X provides Alle with more precise knowledge of her position and thus the payoffs associated with her choices. In the example, perfect information increases the average payoff from 7/3 to 4, nearly doubling her payoff. However, even perfect information is not infinitely valuable, so ignorance may still be a sensible choice if information about A, B, C, and D is costly. In this case, if the cost of information about A, B, C, and D is greater than 5/3, remaining rationally ignorant about X may be optimal.[2]

In such cases, having biased expectations may be regarded as a "rational choice" and the consequences of that choice on one's subsequent actions may also be regarded to be a

[2] Information in the setting characterized is more valuable in the long run (in second-stage choices) than in the short run (first-stage choice), so how much information Alle acquires is also affected by her time discount rate and degree of risk aversion.

consequence of forward looking decisionmaking. In this sense, both biased expectations and systematic mistakes are consistent with rational choice. Alle may make systematic mistakes, but have no regrets.

III. Learning from Mistakes: Natural Ignorance, Surprise, and Regrets

If neither biased expectations nor failures to choose optimal strategies can be called mistakes or "irrational," is there any behavior that can be? Is there forward-looking consistent behavior that can produce regrets? We now shift from the rational ignorance case to the natural ignorance case; that is, from settings in which individuals know all the variables (dimensions) that can possibly be sampled to settings in which some possible dimensions of data, decision trees, or strategies are initially unknown. Natural ignorance occurs when only a proper subset of the potentially available variables and relationships are initially known.

The multidimensionality of all but the simplest phenomena imply that ignorance is commonplace and also that *ignorance does not automatically diminish as sample size or experience, per se, increases*. Rational ignorance can be reduced by gathering information about variables known to exist, but about which one had previously gathered no information. Reducing natural ignorance requires the discovery of previously unknown variables. In sampling terms, reducing natural ignorance requires tabulating previously unknown characteristics of the potential sample at hand.

Natural ignorance generates the same sorts of biases and mistakes as rational ignorance. Decisionmakers will tend to have biased expectations (e.g., ones not fully conditioned on all relevant variables) and will make mistakes in the sense that they achieve outcomes that are inferior to others that are available to them – at least in principle. In addition, surprises may occur, completely unanticipated events may occur. A fully rational individual who neglects relevant dimensions and parameters cannot avoid systematic mistakes and surprise, except through blind good fortune.

Natural ignorance also allows the possibility of rational regrets. Both natural and rational ignorance cause rational individuals to systematically reach mistaken conclusions about the world, regardless of the extent of their experience (sample size) with the setting of interest. However, when one is naturally ignorant, one may learn things that are completely new about the decision environment – at least to the relevant decisionmaker. Such surprises are not always pleasant ones, but both pleasant and nasty surprises may cause one to regret previous decisions – for example, to regard previous informational decisions as mistakes – "I should have known better."

A. Different Modes of Learning

In the previous cases, Alle was assumed to know what she knows and does not know. This allowed informational decisions to be made, which influenced her subsequent planning decisions and actions. We now examine cases in which she may not know what she does not know.

In a setting in which natural ignorance exists, two sorts of learning are possible. First, Alle may gain additional precision about variables that she already knows – for example, additional data about A, B, and C may allow more precise estimates of a, b, and c to be made. Second, she may learn about new previously unknown variables and possibilities. For example, variable D might not initially have been known and might be discovered in the course of experience or experiments. It is also possible that Alle did not know that decision node 3 existed or that choice R could ever therefore be sensible. Indeed, choice R itself may not have been known or considered. (Why learn the shortest way from the beach to high ground, if one has never confronted or heard about tsunamis?)

The first sort of learning can be modeled using the conventional statistical (Bayesian) models of learning. The reduction of natural ignorance cannot be so readily modeled, which is one reason why most economic analysis tends to neglect it (and a related activity, innovation). Eliminating natural ignorance involves a quite different process of learning than routine statistical sampling does.

To see this, 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*.

$$P(s|m) = [P(s)\ F(m|s)/\ F(m)\ ] \qquad (2)$$

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 it*.

Bayesian updating allows refinements of theories that can be represented as conditional probability functions over known events, but not refinements over events ruled out a priori or completely ignored. Learning about "missing dimensions" involves processes that are 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.[3]

B. Learning from Mistakes

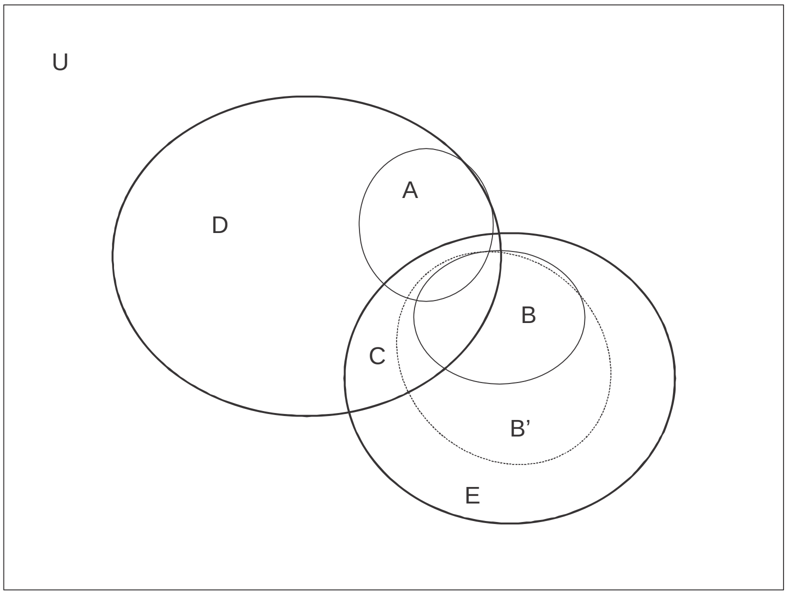
Quasi-Bayesian learning may be useful as long as the results are satisfactory and some convergence is evident. Breaks with this method, innovation or discovery, may be triggered by major failures of that technique, for example, when "impossible" events occur. Systematic errors (when observed) may induce one to reconsider one's premises, look more carefully for new variables and models, and to drop others. When new variables or connections are discovered, one can be said to "learn more from one's mistakes than from one's successes." Mistakes can induce innovation.

For example in figure 2, the initial theory may consist of a conditional probability function that maps set A to set B. If it is subsequently observed that outcomes in the larger set, B', are also associated with events in set A, the theory could be broadened to include these possibilities. The result would necessarily reduce the probability that (at least some) specific elements of A cause specific events in B, because the probability of landing in B given A is now recognized to be less than 1. When the world grows larger and more complex, rather than smaller and simpler, probabilistic relationships become less rather than more certain, because probabilities are spread out over a larger domain of possibilities. Nonetheless, in this example events in A can be said to explain more of the universe than previously believed.

[3] Binmore (1992, p. 488) suggests that a complete list of possible outcomes is not even conceptually possible or at least is beyond the capacity of real decisionmakers. 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 an early analysis of the relationship between Bayesian learning functions and rational expectations. They note many cases in which Bayesian learning converges toward rational expectations. However, they also note failures (inconsistencies) in cases in which the model used by individuals (firms) is incorrect.

Figure 2
Theories as Mappings



In the illustrative choice setting developed above, Alle may not initially realize that node 3 exists and experience a setting in which strategy M generates a payoff of zero. This is impossible if only nodes 1 and 2 exist, which may induce Alle to consider new previously unconsidered possibilities. In this manner, unexpected or impossible outcomes may suggest the existence of alternatives of which one had been entirely unaware.

If Alle initially knew of nodes 1 and 2, and remains otherwise uninformed after learning about node 3, her Bayesian priors fall from 0.5 to 0.33 after she learns about the existence of node 3. She becomes less, rather than more, certain about which node she is at. This contrasts with statistical notions of information based on Shannon and Weaver's (1949) pioneering work on information theory. Within such theories, additional information tends to reduce the variance of the estimates of relevant model parameters. This will not occur if the "new" larger world is more complex (or uncertain) than the "old" world.

Mistakes generated by natural ignorance are analogous to those developed for rational ignorance. However, *natural ignorance is not rational*, and previous choices can be regarded to be suboptimal-mistakes – both informationally and practically given the costs and benefits associated with reducing it. After Alle realizes that she could have learned about node 3 far earlier, she might honestly regret not having invested in discovering that possibility at an earlier point on the decision tree.

Unfortunately, it is not always possible to learn from one's mistakes, because some missing dimensions and relationships are extremely difficult to recognize (distill from experience). Here one might reflect on all the new physical relationships discovered in the past two centuries that would have been very useful a thousand or two thousand years earlier.

IV. Coping with Unpleasant Surprises

An unpleasant surprise occurs when an unexpected event provides information (often freely available) that makes one subjectively or objectively worse off. Some, but not all, unpleasant surprises may induce one to change one's plans and models of the universe. A subset of those surprises may induce rapid revisions in one's immediate plans, because existing plans are found to be less effective or more dangerous than previously thought. Alle's plan to take action M, because she thought she was at node 2.2, would be revised once she realized that she was at node 3.2, although it might not be immediately obvious that R was the best strategy

In some cases, one's existing plans may need to be revised quickly to avoid or reduce great losses. This is what we normally mean by the term "crisis." In other cases, one may have time to analyze the best response and may invest in knowledge that previously seemed too costly to be worth undertaking. In the Alle example, an unpleasant surprise may induce a more careful consideration of R, which previously had attracted little attention, because it was never useful. Finding oneself in an "impossible" position may induce previously neglected actions to be examined more carefully and new strategies adopted.

The time pressure associated with crises tend to reinforce the likelihood of mistaken choices. That an event is a surprise implies that it was unanticipated and unplanned for. Thus, a crisis normally requires making new plans in circumstances that were not previously fully known or analyzed. This is rarely easy and is often impossible. For example, learning that node 3 of figure 1 exists and that strategy R is possible and effective may require more innovation and analysis by Alle than is possible during the period in which a decision has to be made. As a consequence, she may simply play the "safe" strategy M, which yields the worst of the possible in the new circumstances.

As this example demonstrates, natural ignorance is a sufficient condition for unpleasant surprises to emerge within a rational choice framework. It also demonstrates that the terms surprise and crisis have little meaning under conventional assumptions. Had the full set of decision trees been known and analyzed, as usually assumed in game theoretic analyses, Alle would simply have adopted R without hesitation. Without natural ignorance and decision costs, finding oneself at node 3 could not be a surprise and the need to evaluate new strategies could not be a crisis. Had rapid adjustments not been necessary, care could have been taken to understand the consequences of actions at Node 3, as well as possible. Thus, mainstream approaches rule out the possibilities of surprise, crisis, and mistakes.

However, if unpleasant surprises and mistakes are commonplace experiences, it is possible that people will devise plans to reduce their frequency and losses generated by them. Such steps can be analyzed using more or less standard ideas from rational choice-based social science. That particularly unpleasant surprises and crises are unanticipated does not mean that routine procedures for handling crises cannot be designed and implemented. It simply means that perfect solutions are not likely to exist and that improvements are always possible.

A. Robust plans and error correction as methods for dealing with surprise

The informational nature of both mistakes and crises imply that a variety of steps can reduce losses associated with them.

One step that can be taken is the development of robust plans. Plans made in settings in which it is well understood that some possibilities are unknown, or occur with unknown probabilities, normally include “fudge factors” (large reserve capacity) that enable the plans or organizations to function reasonably well even if surprising or unlikely circumstances have to be confronted. Such plans make sense in many stochastic settings, but are especially useful when surprise events are considered likely. The more likely and larger the “anticipated” surprises, the more important robustness will be for a plan’s success.

Planners will also acknowledge that unpleasant surprises can be consequences of calculation and analytical errors, as well as ignorance of possible events. Decisions made in complex circumstances thus also include routines for discovery and correction of policy mistakes at relatively low cost. This is, of course, one reason why elections in democracies are relatively frequent. Similar considerations evidently inform emergency policies that have "sunset" provisions, so that they expire or are carefully reviewed after a crisis has passed and better information becomes available.

A fine-tuned plan or design may fit a particular set of circumstances very well, but not function nearly as well under different circumstances. A well-designed bridge may be able to handle all "normal" loads, but may collapse if loads are surprisingly large or the wind unusually strong. To deal with the unknown (as well as undetected construction and design errors), a robust bridge is designed to carry loads far greater than anticipated or than actually occur. Moreover, after a bridge fails, the result will not usually be simply regarded as a stochastic event. Rather, efforts will be made to understand what, if anything, caused the failure. If a cause is identified, it will be taken account of in future designs.

Such "fudge factors" and error correction procedures would be wasteful in a world where all possibilities are known and no mistakes are made, but are completely sensible in a setting in which surprises are commonplace.

B. Research and development: "brainstorming" as a method of reducing unpleasant surprises

As long as robust plans can absorb the surprises experienced, the usual conclusions of mainstream rational choice models will tend to apply, although those models will not account for fudge factors and error correction, because the latter would be unnecessary in the usual rational choice models. Decisions will be consistent through time and appear to be based on unbiased expectations. No mistakes will be evident. However, an "unusually" large surprise or mistake, or series of small surprises and mistakes can overwhelm even relatively robust plans and organizational designs.

That such surprises result from natural ignorance implies that it is possible to reduce the frequency of unpleasant surprises by investigating possibilities and planning for unlikely (or impossible) events before they happen. For example, a person or group may try to reduce natural ignorance by thinking broadly about possible scenarios. This is a nontrivial task; however, by studying past crises in a broad range of countries it is often possible to learn new possibilities and new scenarios without breaking entirely new ground. In some cases, research can convert surprises into predictable, or at least well understood, phenomena. In other cases, the research may reveal that a wide range of unpleasant surprises usually produce a far narrower range of unpleasant consequences.

Consider a broad class of surprise events that fall in set A (of figure 2) and generate consequences scattered throughout set C. Suppose that many of these were unique events with many different characteristic, but that historical frequencies suggest that the consequences of A-type surprise events fall mostly within set B. In such cases, the consequences may be easier to condition plans on (and be better understood) than the phenomena that generate them. (Rain and wind produce surprise events with a wide variety of consequences, but most consequences fall within well-understood ranges.) Even if one does not know exactly why an event happens, nor cannot predict when it will happen, to take steps that reduce the losses from its most common consequences.

Common features of the consequences generated by quite different surprise events, often allow a relatively simple robust conditional plans to be devised, which reduce the losses generated from most such events. For example, one can never fully anticipate the exact time and place of an earthquake, flood, contagious disease, or terrorist attack, but many of the consequences of such events are similar. There will be disruptions of ordinary markets for life's necessities and medical problems that can be addressed by creating one or more organizations that can provide health services, food, water, and shelter on short notice. As responses are worked out, the losses associated with such unpleasant surprises may be bounded, although the surprises continue.

Associated institutions and robust response plans may be so successful, that many such surprise events stop being considered crises, as crimes and fires are not often regarded as crises, although particular instances differ in surprising ways and the results are nearly always unpleasant.

C. Ex post crisis insurance and bailouts as responses to unpleasant surprises

A common method for bounding the losses associated with unpleasant surprises is ex-post social insurance. The person's receiving the "insurance payout" are those harmed by an unpleasant surprise and (at least in principle) only those harmed. However, unlike ordinary insurance, ordinary premiums sufficient to pay for the insurance was not paid by the pool of potentially parties. A robust emergency insurance program may have reserves (stocks of food, clothing, shelter, and medical supplies) sufficient to deal with “commonplace emergencies” but not “unusually” large ones.

Such “bailout” programs may be devised by groups that have similar exposures to unpleasant surprises or by a government that represents large numbers of persons exposed to such risks and uncertainties. Not everyone in such groups may be subject to the same surprise events, because of regional differences in the historical frequencies of various unpleasant surprises (hurriacanes, earthquakes, river flods, tornados, epidemics, power outages, etc.). However, insofar as the responses (pay outs) to the surprise events are similar, the same reserves and delivery programs can be used to address consequences associated with a variety of unpleasant surprise events.

Again such programs may robust, with large reserves, but still occasionally be overwhelmed at which point payment for the coverage (bailout) can only be provided after the fact. Reserves may be entirely consumed, and more, by a particularly large, unpleasant, surprise.

The emergency provision of healthcare, food, water, and shelter, may be considered a form of ex post insurance. Similar ex post insurance programs may also attempt to replace income and assets lost from unpleasant surprises that cannot be fully insured. Again, qualifying for such programs is similar to ordinary insurance programs, because only those damaged by the surprise qualify. Again, the cash payments may come from reserves (funds) that are “usually” sufficient for the required payouts. Such programs often “bail out” those whose losses are greatest and whose problems may have produced subsequent crises (pandemics, civil disorder, or bank runs).

Again, some surprise events are too large or unusual to be paid out of such pre-paid funds assembled before the event. This implies that the largest payouts will be paid for after the event, if at all. Ex post insurance, by its nature, is difficult for private markets to provide, because the payments go to those damaged by events that were not widely anticipated and so could not be prepaid in the normal way with insurance fees. Consequently, ex post insurance is normally provided by nonprofit agencies and governments, rather than private firms.

Unfortunately, if used routinely for all unpleasant surprises, bailouts may contribute to subsequent crises by weakening incentives to adopt robust (prudent) plans. For example, more expensive, but fragile, housing might be built in flood plans or along sea coasts, and financiers may adopt riskier (less robust) investment strategies, with smaller private provisions (reserves) set aside for unpleasant surprises. Ex post insurance programs are not always trivial in size, as evident in the most recent financial crisis, and the increase in the magnitude of "surprise payouts" tends to be magnified by changes in behavior of those who expect to be bailed out.

As a consequence, routine bailout policies can also exacerbate crises – as might be said of the Irish government's 2008-10 response to its banking crisis. By promising too much, an entire government or economy's finances may be undermined, by being exposed to new unpleasant fiscal surprises associated with such promised "emergency" support. This suggests that robust bail out programs will limit, rather than eliminate, the extent to which those affected by unpleasant surprises are insured against losses.

V. Crisis Management

Unfortunately, experience suggests that unpleasant surprises and their consequences do not always fall within neat, easily handled bounds, and so planning, robust plans, and bailouts also occasionally fail. The world is not simple and small enough to avoid all unpleasant surprise or limit their losses at an acceptable cost – if it is possible at all.

A. The nature of a crisis and the nature of crisis management

At times when robust plans and ex post insurance programs fail, active crisis management becomes necessary. In such cases, old plans may no longer be feasible (the bridge is out), or may now yield such low payoffs that new plans, even if mistake prone, are likely to be improvements over current ones. One has to run for the hills before a tsunami wave arrives. Taking a route that is a bit longer and leads to a somewhat more distant hill than necessary may produce a better result than sitting down, pulling out a map, and determining the quickest route to the closest hill likely to remain above water. By the time this analysis is undertaken, the decisionmaker may be underwater.

During times of crisis, existing plans have to be quickly revised to limit losses. The problems associated with crisis management thus include those associated with surprise events and ignorance, but also include problems associated with the need for a quick response in a setting in which the options and consequences of one's actions are not fully understood. Crisis managers are ignorant of the best alternatives, and are not likely to discover the best response to the new circumstances in time available. Responses to crises, thus, include analytical errors, as well as mistakes associated with ignorance.

The problems associated with crisis are analogous to that of numerical analysis of process that cannot be easily represented as a function or correspondence, and so cannot be analyzed with conventional mathematical tools. A function may not be concave or continuous, yet still have a maximum. That maximum (best action) may be found through systematic trials and error – using a "hill climbing" algorithm that maps some domain of circumstances (C) into possible decisions and results (D). A hill climbing program substitutes values (c_i) into a simulation or function with complex properties and computes the value [$d_i = f(c_i)$], and then tries to find other values (c_j) that produce a higher result ($d_j > d_i$). This process is repeated until no higher points on the function can be found. Each step takes time to compute, and when only a limited number of steps is possible, because of time constraints, one is unlikely to find the exact maximum of even fairly well-behaved functions. To make this less abstract, consider the difficulty of finding the highest point in a hilly area or local mountain range in just a few days, without a map or compass.

Natural ignorance and the need for a rapid response imply that decisions reached during a time of crisis will be unusually error prone. Even in cases in which the best response is potentially knowable [as in the case where $d_i = f(c_i)$, for all $c_i \in C$, with $d_i \in D$ and $D \in R$], the best response is not likely to be identified in short time period, unless the relationships of interest are fairly simple. Careful analysis and planning generally produce better results than quick reactions, because they allow a more thorough evaluation of alternative strategies, given what is known, and also because additional time allows further reduction of natural ignorance. During a crisis, the short-run advantages of rapid response trump (or appear to trump) those of careful analysis and planning.

Such settings were so common in former times that we (and many other animals) have genetically transmitted rapid response mechanisms, the "flight or fight" reaction. In civilized society the "fight or flight" reaction is rarely needed and/or rarely induces the best immediate response, because crises differ from those in our less organized past. Evidently, mankind's institutional and cultural innovations have reduced the frequency those ancient natural crises, and so there is usually a bit of time for reflection in most crisis settings, although not as much as in normal times. The socially transmitted "take a deep breath" norm encourages a bit of calm analysis before reacting to an unpleasant surprise. Not all such surprises are crises.

Nonetheless, unpleasant surprises that are best responded to quickly are relatively common, and most people have routines for dealing with minor crises (although panic remains a common initial reaction).

Most organizations use a broad cross-section of their personnel to address unpleasant surprises such as equipment failure, personnel health problems, and supply-chain timing problems. Such problems are in a sense predictable, that is to say they are "bound to happen," but the details vary widely and unusual cases will require creative efforts to solve the associated problems within and among organizations.

In large organizations, significant specialization with respect to types of crises often occurs. Crisis response teams may also have responsibility for devising robust plans that avoid the need for rapid creative responses through contingency planning and reserve capacity. Within most organizations, delegation and specialization are used to reduce damages from quick decisions. Small day-to-day crises are handled at lower levels of authority. Any mistakes made by low-level managers will tend to have smaller damages and be easier to correct.

For much the same reasons, streamlined decisionmaking procedures during times of crisis tend to be narrowly focused on the crisis at hand in order to reduce agency problems and mistakes. Clear lines of responsibility are also useful, so that mistakes, malfeasance, and incompetence can be readily identified and punished. The same approach allows managers to be assessed for their relative abilities at crisis management – creative successful responses to nasty surprises – and promoted if they are unusually skilled at crisis management. The larger the crisis, the further up an organization's decisionmaking hierarchy it tends to be addressed.

Extreme cases, existential crises, will involve top management, who may task crisis management teams with discretion to make a variety of decisions without much immediate oversight. Major crisis response problems can be subcontracted to organizations that specialize in crisis management, but such subcontractors are unlikely to be given direct authority to respond to major emergencies.

That mistakes often result from crisis management has given rise to a variety of common expressions for such mistakes: “decisions reached in the heat of a moment” or “during the fog of war.” Because such mistakes are anticipated, standing procedures for addressing crisis management normally include ex post review and error correction procedures.

That less review and analysis are undertaken before decisions are made, does not mean that crisis management decisions are ever carefully reviewed, only such reviews can only be undertaken after many of the response decisions are made. Because more mistakes tend to be made during times of crisis than in ordinary times, procedures for review are even more likely to be useful after a major emergency.

Procedures for ex post analysis, review, and error correction would not be necessary unless mistakes and agency problems were commonplace and/or costly.

B. Democratic Governance and Crisis Management

All organizations face crises of various sizes, and governments are not exceptions. In addition to the usual range of unpleasant surprises associated with the production of services and enforcement of laws, voters often require their governments to take steps to reduce unpleasant surprises in the private sector (as with health and fire code regulation, and with banking and insurance regulation). They are also likely to demand that governments provide ex post crisis insurance in areas in which private insurers fears to tread – often because unpleasant surprises are deemed too commonplace. As a consequence, the scope of governmental involvements in crisis and crisis management is unusually broad. Indeed, it can be argued that risk management, insurance, bailouts, and crisis management motivate most of the expenditures and regulations undertaken by democratic governments. The large scale of government operations and the ability to use taxation to provide resources for ex post insurance programs and crisis management allow government to address many problems not addressable by private organizations.

However, dealing with unpleasant surprises remains problematic within all organizations, and the magnitude of government efforts may produce other problems – many of which will be unpleasant surprises for voters. Crisis management by governments tends to be somewhat more problematic than that by individuals and organizations, because monitoring and error correction are difficult to motivate and implement in democratic organizations. Voters, as well as bureaucrats, will be affected by both rational and natural ignorance. But, both elected officials and bureaucrats may try to hide, rather than repair, their own mistakes. This is often easier to do during times of crisis.

Crisis management naturally tends to increase the discretion of policymakers, while reducing monitoring and control by voters. Greater discretion is necessary to take the rapid steps necessary to reduce losses. Moreover, officeholders are unlikely to have previously stated how they will address the particular crises that emerge under their "watch," so their strategies will not have been reviewed by voters, editorial writers, or think tanks. Crises also increase the knowledge asymmetries between voters and government experts.

Both mistakes and political agency problems thus tend to be larger during times of crisis. Recognizing this problem, voters will demand more information. They will read more newspapers, watch more news on television, which in turn will solicit information from "experts" of various kinds (whose relative merits are difficult to access). Policy-relevant information will also be supplied by organizations with relatively more information on the issues that have to be addressed during the crisis, because their own interests are affected by the crisis.

Voters will have little direct experience with the problems and solutions proposed during times of crisis – essentially by definition, so they are less able to judge the quality of the information supplied. Few voters respond to floods, financial crises, or terrorist crises in the course of their ordinary lives. Relatively greater voter reliance on secondhand information makes them more susceptible to manipulation during times of crisis, than in policy areas in which voter assessments of policy are more firmly rooted in their own independent observations and judgment. Being aware of their own relatively greater ignorance, voters will defer to governmental and other experts during times of crisis.

All these effects tend to alter the informal balance between voters and elected officials in the short run in a manner that reduces voter control over public policy. Bureaus may secure larger budgets and interest groups may be able to secure more favorable tax or regulatory treatments than possible during ordinary times, because voters and their elected representatives are more willing to accept the arguments and assertions of agency experts in times of crisis than in ordinary times. They are also less able to monitor policy decisions, because many decisions are being made rapidly and simultaneously.

Increased dependence on secondhand information tends to reduce the ability of majority rule to function as an efficient information aggregation process (Congleton 2004), and the need for rapid responses largely rules out the use of referenda and elections as decisionmaking procedures. Indeed, the increased influence of interest groups and demand for news during times of crisis provides such groups with an incentive to "manufacture" public policy crises. "Ideological shirking" may also increase as elected politicians may advance policy agendas of their own with less fear of voter retribution (at least in the short run) or simply use their ideologies as a lens through which to understand the events at hand.

This reduction in the effectiveness of voter and legislative oversight is important because government decisions affect so many people and resources, which implies that mistakes are more likely to produce crisis cascades: a series of connected crises that require rapid policy decisions.

C. Robust Constitutions

All of the predictions about other groups and organizations will apply to well-run governments, as well as to smaller private organizations. Governments will have standing routines for bounding losses from unpleasant surprises: analysis of possible crisis scenarios, robust plans and institutions, with fudge factors and reserves will be evident. Delegation, review, and error correction procedures will be adopted to reduce losses in the short and long run. The nature of the losses of interest to political decisionmakers, however, tends to differ from those in private organizations. The goals of organizational actors are always at least partly institutionally induced by the organization's own selection and reward procedures. In the case of national governments, those standing selection and reward procedures are determined by constitutional law and other durable quasi-constitutional rules and norms. Lost votes, for example, will be more important to elected official, than lost dollars.

There are a variety of methods through which potential losses associated with delegating crisis management authority can be bounded. For example, to assure that emergency decisionmaking procedures are temporary and that normal decisionmaking procedures are reinstated as quickly as possible, the standing procedures of crisis management may specify persons (other than those charged with crisis management) to determine when the crisis has ended. Similarly, the legislature, or legislative committees, may formally delegate only temporarily authority to a crisis manager or to the chief executive that expires after a predetermined period.

The mistake-prone nature of all crisis management implies that durable rule changes – constitutional amendments – during times of crisis should be avoided to the extent possible, because changes in the fundamental procedures and constraints of governance are difficult to reverse. This is another reason why the constitutional amendment procedures of robust governments tend to be more difficult to satisfy than those for adopting ordinary laws. Such rules make it less likely that constitutional mistakes will be made during a crisis.

Even during an extraordinary crisis in which constitutional procedures fail, temporary, rather than permanent changes to decisionmaking processes are preferable to constitutional reforms. Constitutional mistakes can be far more costly than ordinary policy mistakes, because they are more difficult to reverse than policy mistakes. To avoid durable mistakes, procedures for dealing with crises and constitutional amendments should be designed, implemented, and revised during times that are relatively free of crisis. As noted above, given time for careful analysis and review, fewer mistakes are likely to be made.[4]

A constitution that has stood the test of time is likely to have procedures for crisis management are robust and relatively crisis proof themselves. This does not mean that they are completely crisis proof, but that for the range of crises experienced, the crisis responses have evidently not exacerbated the crises addressed and have not overridden, threatened, or undermined the government's core decision procedures and constraints.

Through time, a wide range of crises will be experienced, which allows constitutional designers and reformers to learn from the mistakes of past designs, even if they cannot, themselves, imagine all future unpleasant surprises or crises. Durable constitutional regimes encourage prudent contingency planning, effective crisis management, and error correction.

[4] It should be noted that many constitutions lack such provisions, and have been undone by "temporary" delegations of authority to a general or chief executive. For example, Napoleon, Mussolini, and Hitler gained their great discretionary authority largely through emergency powers provisions of their constitutions.

D. Surprise, crisis, and scientific progress

As noted above, crises often create opportunities to learn from unexpected events, consequences, and mistakes. Both pleasant and unpleasant surprises encourage old plans to be revised and new theories to be developed, as noted above. The same logic applies to scientific and technological progress, in general. The work of individual scientists and scientific organizations is often punctuated and accelerated by surprises, unexpected results, unlikely coincidences, and anomalies. This is one reason why the experimental method has proven to be so useful. Indeed, even unplanned lab experiments (accidents) can produce useful surprises. For example, lab accidents created both nylon and penicillin, two major modern discoveries. "Impossible" outcomes (anomalies) often stimulate the formation and testing of new theories that occasionally make the formerly impossible completely predictable.

Anomolies (unpleasant surprises, given a particular theory) often induce a subset of scientists to consider entirely new issues and possibilities, at the same time that ordinary research continues. In many cases, their efforts fail and the puzzles remain unsolved. In a few cases, however, a significant reduction in natural ignorance occurs as "breakthroughs" are made. In this manner, a scientific community often learns from its own mistakes and surprises, but also from tacking unexpected new problems outside their previous range of expertise (Burke 1995). As a consequence, scientific progress often occurs when surprise events become theoretical nuisances for much the same reason that innovation at the level of individuals tends to be accelerated by unpleasant surprises and personal crises. It allows scientists to break free of their more or less routine Bayesian processes of learning.

It bears noting that not all scientifically relevant crises are intellectual ones. Similar scientific advances are often stimulated by large-scale crises such as wars, epidemics, and major recessions, for many of the somewhat similar reasons. Moreover, urgency would not generate policy problems without knowledge problems, and this tends to be obvious during times of crisis. A crisis increases demand for policy-relevant information, and new expenditures on data and analysis often produce useful knowledge. New expenditures, both private and public, tend to reduce natural ignorance in fields that can help ameliorate the current crisis or prevent future crises. In this manner, major social crises may indirectly promote both scientific and technological breakthroughs, what Kuhn (1995) calls paradigm shifts.

There are many cases in which major innovations have been produced as part of a response to a major crisis. For example, the list of scientific and engineering innovations developed during times of war is impressive. Among these were the mass production of penicillin (which Fleming had never been able to master), synthetic rubber, radar, early computers, jet airplanes, rockets, nuclear fission, and a host of technologies without obvious peacetime applications. As the saying in English goes, “necessity is the mother of all invention.” Necessity is often a by-product of surprise and innovation a consequence of reductions in natural ignorance induced by surprise.

VI. Summary and conclusions

This paper has argued that ignorance is widely recognized to produce a variety of problems and that attempting to bound the losses of such problems produces a variety of more or less predictable responses by forward looking decisionmakers. Thus, although the existence of ignorance undermines several presumptions about rational behavior, it also produces explanations for a good deal of behavior that might otherwise have been deemed irrational. Given information costs and natural ignorance, expectations will be either because information is too costly to be collected, or because the information necessary to form unbiased estimates is beyond the scope of an individual’s knowledge. Insofar as unbiased estimates are necessary for decisionmakers to make the right choices, even forward looking consistent people will make systematic mistakes in their daily lives, although they may have few regrets.

Natural ignorance also allows the possibility of genuine behavioral innovations, which implies that the observed behavior of individuals, who are fundamentally consistent, will appear to be inconsistent through time. The latter is not a problem for the individuals involved, but for theorists who anticipates observing consistent behavior as consequence of assuming both rationality (forward looking consistent decisionmaking) and complete knowledge of the decision environment. Given the possibility of surprises and innovation, inconsistent behavior may simply demonstrate that a problem (surprise) has been addressed and solved.

That surprises and mistakes are common provides individuals with evidence that natural ignorance exists, without providing information about what they are ignorant of. That indirect knowledge of their ignorance provides forward-looking decisionmakers with good reasons to take a variety of steps that can be taken to cope with surprise events. For example, they will adopt plans that are robust, rather than optimized in all details. Simon's (1955, 1978) observations about rules of thumb and satisficing behavior are likely to reflect efforts to achieve such robust plans. Robust plans do not maximize risk-adjusted expected values in the usual sense of the term, but yield results that are acceptable and avoid catastrophes in a broad range of circumstances – not all of which are known beforehand.

Organizations, similarly will adopt robust plans, and also adopt robust decisionmaking procedures that can cope with large and small surprises in a manner that limits losses from them. Authority will be delegated to "low"-level members of management to "put out fires," because such fires need to be put out or they will cause major problems for the organization. Mistakes can be corrected and long run plans improved after short run decisions are made.

As part of those plans, reserves of various types may be created as a means of bounding the losses associated with the "usual" unpleasant surprises. These insurance-like funds are not truly instances of self insurance, because by unpleasant surprises are unanticipated and not easily represented in the usual statistical manner. They are uncertain events rather than risky ones, to use Knight's terminology. Thus, it is difficult to design prepaid insurance instruments to cover all surprises, and profit-making firms will not sell such policies, because it is known that a single large unpleasant surprise (major earthquake, hurricane, or nuclear disaster) would bankrupt the company. Indeed, the recent meltdown of mortgage-backed security markets reveals how difficult it is to cope with even relatively modest unpleasant surprises – a totally unexpected 20 percent decline in housing prices.

That such surprises are acknowledged to be possibilities, implies that government involvement in risk management is both necessary and likely. Some types of regulations that can reduce unpleasant surprises may be unlikely to be adopted by for profit companies, because they may profit in the short run by gambling that "they" will not be surprised or be gone before a nasty really surprise occurs. Ex post insurance may be demanded, but many not be provided in the private sector. These suggest that governments are likely to play a significant role in managing major unpleasant surprises in the "private sector," as well as ones that emerge in its own service and regulatory domains.

Yet government efforts to reduces losses from unpleasant surprises is problematic for several reasons. Mistakes are inevitable during times of crisis, because natural ignorance affects policymakers, bureaucrats, and voters. Moreover, information asymmetries increase and the resultant agency problems allow some interest groups, firms, and individuals to profit from the rapid, weakly monitored decisions that are required during times of crisis. Otherwise robust democratic constitutions, as opposed to more authoritarian ones, may fail during times of crisis because they fail to properly delegate and constraint emergency powers deemed necessary during times of crisis.

To conclude: this paper has argued that behavior associated with self-acknowledged ignorance is of both theoretical and practical interest, although it is widely left out of rational choice-based models of economic and political decisionmaking. A variety of steps will predictably be taken by forward looking decisionmakers who are aware of their own ignorance and/or continually surprised by the circumstances they face. Decisions and programs that reduce losses from unpleasant surprises often look different from those which maximize expected values. They have larger reserves, include provisions for error correction, and are, nonetheless, occasionally inadequate.

The large number of cases in which ignorance affects personal, organizational, and governmental behavior suggests that the neglect of ignorance and surprise by mainstream economics may unnecessarily and mistakenly limit the scope of rational choice-based analysis. Ignorance is not bliss, but neither is it irrelevant for social science research.

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