Decisionmaking, Risk, and Uncertainty: An Analysis of Climate Change Policy

Kruti Dholakia-Lehenbauer and Euel W. Elliott

This article explores four questions. First, what theoretical frameworks help describe policy failure and success? Second, how might the decision that leads to failure or success be understood in terms of differing concepts of rationality and decisionmaking? Third, how does the discussion of risk and uncertainty as originally proposed by Frank Knight (1921) apply to a better understanding of both the first and second questions? Fourth, what is the relationship between serial and parallel processing and how are these administrative systems related to important aspects of the prior questions? Our chief contribution in this article is to show the ways in which these questions and their respective theoretical frameworks are interrelated as applied to one important contemporary policy question—climate change. We think our proposed integration of the various literatures offers important insights into the challenges policymakers face in deciding whether or not to adopt a particular policy.

The first question is based on the notion that decisionmakers can commit two fundamental types of policy errors: the wrong policy can

---

Cato Journal, Vol. 32, No. 3 (Fall 2012).

Kruti Dholakia-Lehenbauer is an Associate Faculty member in Economics at Collin College and Euel W. Elliott is Professor of Public Policy and Political Economy at the University of Texas at Dallas. The authors wish to thank the referees and the editor for their useful comments and guidance in writing this article.

be implemented or there can be a failure to implement the needed policy. Based on work by Heimann (1993), we construct a simple model of hypothesis testing using Type I versus Type II errors that is common in the social and behavioral sciences.

The second question is based on Vernon Smith's (2003) discussion of two fundamental types of decisionmaking: constructivist and ecological. The former approach, which has important similarities to expected utility theory, represents a highly deductive, top-down approach that places a high degree of confidence in model building and the ability to make accurate predictions about phenomena over extended periods. The latter represents a more bottom-up strategy that assumes decisionmakers do not have all encompassing information available to them and thus rely on heuristic models of decisionmaking. Such decisionmaking does not reject theory, but allows for theory-building to be done incrementally with ongoing adjustments of beliefs.

The third question provides an analytic framework for evaluating the probability of different kinds of events. Knight (1921) drew the important distinction between risk and uncertainty, and the consequences for understanding the probability of the occurrence or non-occurrence of particular events (see Raines and Jung 1992, Jarvis 2008). Risk refers to a calculated and predictable outcome, whereas uncertainty refers to an event for which the probability of outcomes is difficult to objectively measure. We believe that policymakers, as well as policy analysts, are all too likely to misinterpret one set of events for another, leading to faulty policymaking.

The final conceptual framework in which we examine the relevance of the forgoing issues to questions of administrative systems offers additional and important insights into the nature of decisionmaking in organizations. Ultimately, we think our analysis offers a roadmap for future research that will be of assistance to scholars and decisionmakers in better understanding decisionmaking and its consequences.

In the following section, we discuss the desirability of policy action or inaction (Type I versus Type II errors). We then move to a comparison of constructivist as opposed to ecological decisionmaking and the distinction between Knightian risk and uncertainty in the subsequent two sections. We then apply our arguments to the issue of climate change.

To Act or Not to Act: The Nature of Policy Success or Failure

What is the nature of policy success or failure? Many scholars have explored that question from the standpoint of what happens after a decision has been made. Our approach is somewhat different. Instead of asking how many resources are devoted to a policy or how principal-agent problems influence policy outcomes, we inquire about the fundamental nature of decisionmaking—that is, should one act or not act? Of course, we recognize that the decision of whether or not to act is fraught with uncertainty and is based on a subjective assessment of the probability of success (or failure). Yet focusing on it helps capture the most fundamental choices that policymakers face.

One important contribution to this research is the work of Heimann (1993), who builds on work by Perrow (1984) and Landau (1969), who pioneered research in the area of organizational failure and the need for organizational redundancy. In his discussion of the decisions leading up to the Challenger Space Shuttle disaster of January 1986 (see Vaughan 1997), Heimann notes two types of policy errors. In the first type (Type I error), the wrong policy is implemented. In the second type (Type II error), the correct policy action is not implemented. The former represents an error of commission, and the latter an error of omission. Figure 1 presents the stylized model developed by Heimann.

Decisionmakers face two possibilities when confronting binary choices: act or not act. We know the correct decision was to take action—that is, stop the launch. The decision taken, however, was to do nothing—that is, allow the launch to proceed when it should have been aborted. This resulted in a Type I error. And, as already noted, it is crucial to recognize the unavoidably subjective nature of the assignment of probabilities to committing a Type I versus a Type II error. Heimann (1993) makes a strong case that, given the knowledge available to NASA, committing a Type II error (wrongly stopping the launch) was preferable to committing a Type I error (wrongly launching), even if the probability of failure had been determined to be remote. In other words, halting the launch of Challenger was a small price to pay to avoid a possible failure, even if the chances were good there would be no failure.

FIGURE 1
Type I and Type II Errors

		Proper Course of Action	
		Take No Action	Take Action
Decision	Take No Action	I Correct Decision	II Type I Error
	Take Action	III Type II Error	IV Correct Decision

Contrasting Approaches to Decisionmaking

Here we examine and contrast two different rationality assumptions to decisionmaking: the constructivist and the ecological approaches. Both have their place in formulating and designing policy, under different conditions and contexts having to do with the information available and the costs of making the wrong decision.

Constructivist rationality is based on the logic of Descartes (Cartesian logic), which advocates that human reason can deductively construct human institutions through the conscious molding of human behavior. Cartesian logic is based on the notion that either society derives its structure from the top down along rational principles or through conforming to the preferences of a social planner who could know objectively what is “best” for the society.

An alternative to constructivist rationality is ecological rationality, which is closely related to the principles and assumptions of bounded rationality. Smith (2003: 470) notes, “Ecological rationality uses reason—rational reconstruction—to examine the behavior of individuals based on their experience and folk knowledge . . . to discover the possible intelligence embodied in the rules, norms, and institution of our cultural and biological heritage." Thus, ecological rationality is a decisionmaking process that emerges out of cultural and biological evolutionary processes utilizing the homegrown principles of action, norms, traditions, and morality. Decisionmakers, acting on the assumptions of ecological rationality, develop rules of thumb or heuristics in decisionmaking. This approach implies that determining global optima or maximizing strategies for a particular problem may not be possible.

From the perspective of decisionmakers, the implications for constructivist versus ecological rationality are found in the kinds of policy steps to be taken or the policy actors themselves. Those differences are captured in Table 1. Constructivist rationality can lend itself to sweeping, transformative policy change by suggesting that we have sufficient information available to decide what the optimal policy strategy is. Of course, it can also be used to justify the maintenance of the status quo to the extent that existing policy is based on confidence in our understanding of the world. Constructivist rationality relies on the assumption that forecasting

TABLE 1
Foundations of Constructivist vs. Ecological Rationality

	Constructivist	Ecological
Assumptions about availability of knowledge	Complete or near complete	Incomplete
Confidence in ability to forecast future	High	Low
Fundamental view of state	High confidence in ability of state to act—"social engineering"	State has limited competence
Approach to solutions	Sweeping and transformative	Evolutionary

models are sufficiently accurate to be used for making long-range forecasts. More generally, it makes the assumption, whether explicit or implicit, that we are confident in our ability to understand the world around us and the complex causal structures of various phenomena.

Ecological rationality suggests that policymakers have to be more humble in their assumptions about what they can ascertain about the future. They might have information, but they also need to recognize that the world is a complex system subject to instability and constant change, and may often exhibit highly nonlinear kinds of behavior that make prediction difficult, especially in the long run. Uncertainties exist regarding the very nature and extent of the problem, as well as uncertainties regarding the preferred course of action. The preferred course of action is evolutionary, incremental, and based on the ongoing flow of available information.[1]

Knightian Risk and Uncertainty

Frank Knight (1921) defined three types of probabilities: a priori, statistical, and estimated. A priori probabilities are determined under circumstances where the universe of known outcomes is defined, and through application of deductive logic, probability can be objectively calculated. Games of chance (e.g., the rolling of dice or poker) are examples of outcomes where the probabilities are a priori in nature. A priori probabilities are measured quantitatively, possess high levels of objectivity, and have low levels of uncertainty. The probability of drawing the ace of spades from a fair deck of cards is 1 in 52 or 1.923 percent. The probability of rolling two sixes in a game of dice is 0.0278 ($= 0.1667 \times 0.1667$). Examples are measured quantitatively, they are completely objective, and there is no uncertainty. The probabilities of these events occurring are a mathematical reality. Games of chance are at the extreme (high) end of the risk scale. Very few decisions that have to be made in the world of public policy carry this kind of precise characterization of possible outcomes.

[1]It is fair to note that Smith (2003) clearly views ecologically based rationality and decisionmaking as superior to constructivist approaches. We are more agnostic, believing both approaches have potentially important advantages (and disadvantages), although we do think that ecological rationality, with important caveats, may be more applicable in many cases.

Statistical probabilities are less objective. The universe of probable outcomes can be broadly classified, but not all possible outcomes can be fully known. Such probabilities are inductively defined, from experience and observation. A good illustration would be predicting the likelihood of snow on Christmas day. Past observations and sampling play an important role in determining the likelihood of such an event. Statistical probability can be accurate and therefore possess strong risk characteristics, but because of the low objectivity aspect the uncertainty factor remains high.

Estimated probabilities are altogether different. The universe of possible outcomes can only be anticipated based on subjective evaluations. It is extraordinarily difficult if not impossible to determine the frequency of some event because the event itself is unique or its frequency extremely low. Thus, estimates of an event are strictly subjective. Moreover, unlike a priori or statistical probabilities, estimated probabilities can lack consistency. For instance, an individual may like movie A more than movie B, movie B more than movie C, but movie C more than movie A. This is an example of an intransitive choice set, and such outcomes may appear quite often in various social dilemmas (see Riker 1988). Such probabilities, based on individual choices and subjective evaluations, inherently run the risk of being unreliable and volatile. Unlike the more objective types of probability, estimated probabilities result in low accuracy of measurement and objectivity and are highly uncertain.

What should be obvious is that the description of statistical and estimated probabilities represents the kinds of choices that confront policymakers under most circumstances. Broadly speaking, policymakers are confronted with decisions that are made under varying degrees of risk, uncertainty, measurement accuracy, and objectivity. Most important, we believe policymakers, and major segments of the public, tend all too often to confuse the concepts and critical distinctions made by Knight. The result is bad public policy, with negative consequences for the economy and society. Simply put, if policymakers *assume* some harmful phenomenon or event is certain or near certain to occur and they act to mitigate it, they may turn out to be wrong about the true likelihood of that event and have committed costly resources in a wasteful fashion. Meanwhile, if policymakers fail to act because they think the probabilities are too "fuzzy" and the possibility of harm too uncertain—and they are wrong—then the failure to act could be catastrophic. So how do they know when to act or not to act? The answer is that we do not know for sure, but there are possible guidelines, which we now will examine in the case of climate change policy.

Climate Change and Decisionmaking

We do not intend to engage in a detailed examination of the different positions expressed concerning climate change. Rather, we merely seek to use this policy controversy as an example to illustrate our integrated theoretical framework. With regard to the substantive debate, a vast number of opinions have been expressed. For example, Stern (2007) argues that anthroprogenically induced climate change represents a profound threat that must be addressed immediately in order to avoid future disaster. Others (e.g., Singer 1997) argue that warming is occurring but is due mostly to solar cycles and not predominantly to human activity.

The climate change group argues that global warming must be dealt with in dramatic fashion through major policy interventions designed to reduce the amount of carbon dioxide and other greenhouse gases that are emitted into the atmosphere (Gore 2007, Stern 2007). Others contend that warming is occurring but that technological solutions commonly referred to as geo-engineering, can reduce the threat from greenhouse gases. These approaches include carbon removal, or "scrubbing" to capture CO_2 from the air, or using technologies such as dust particles designed to reflect or absorb sunlight (Jackson and Salzman 2010: 68). Caldeira and Wood (2008) contend that geo-engineering strategies can be effectively utilized in polar regions and globally to mitigate the effects of greenhouse gases. Other strategies might be considered more biological in nature and include large tree planting efforts in order to create carbon sinks.

Occupying something of a middle ground in the climate change debate are those who accept that climate change and global warming are a reality but express doubts about the severity of the problem (Tol 1995). Others question the social costs of some of the proposals made by Stern and others, and make a case that more modest and incremental strategies are appropriate even while agreeing that climate change is a major threat. For example, Nordhaus (2007, 2008) expresses concern that those such as Stern who call for decisive action to reduce greenhouse gas emissions use relatively low discount rates around 1.3 percent, rather than a more realistic rate of about 4 percent.[2] Still others argue from a methodological perspective, suggesting that simulation models have important limitations that curtail their usefulness in making predictions about climate, and thus suggest caution in using climatological simulations to inform extreme policy decisions (see, for example, Hall, Fu, and Lawry 2007; Hall 2007).

Although it is certainly fair to say that the majority of scientific opinion has probably been in favor of something like Stern-Gore or similar approaches, there are a very significant number of dissenters (e.g., Nordhaus 2007, 2008), with the disagreement primarily over the pace at which greenhouse gases can be reduced without damaging economic growth.

What Is to Be Done?

Basically, multiple options are available to policymakers. They might do nothing and hope that the threat does not materialize; they can take dramatic action along the lines proposed by Stern-Gore and others (the two extremes); or there might be an array of middle ground solutions. For the sake of simplicity, we assume there is a binary choice set: "dramatic action" (which we define as policies designed to yield 75–90 percent reduction in emissions) and "everything else." "Everything else" includes strategies from a wait and see approach to determine after additional data are available (i.e. "do nothing," at least for the time being) whether to take dramatic action, or incremental steps that could include an array of efforts to reduce emissions over some amount of time. The real world of policymaking is more complex, but the binary choice model, for our purposes, is initially used to simplify the discussion.

Figure 2 presents the basic decision matrix of policymakers similar to the example in Heimann (1993). Decisionmakers in our

[2]The idea of the discount rate, of course, is to compare present-day gains and losses with future gains and losses. If you can save X amount of damage caused by climate change in some future year, say 2100 AD, by spending one dollar on reducing greenhouse gas emissions today, how large must X be to make the investment economically worthwhile? The higher the discount rate, the larger X must be to make the investment worthwhile. The implication is that the higher the discount rate, the more difficult to justify dramatic policy action. The main point though is that there is inherent uncertainty as to what the true discount rate should be.

FIGURE 2
The Basic Decision Matrix of Policymakers

		Choice 1		Choice 2
		Incremental Action—Mild Mitigation	No Action	Dramatic Action
Proper Course of Action	Take No Action	I Correct Decision		II Type I Error
	Take Action	III Type II Error		IV Correct Decision

model choose between "do nothing/take limited action" and "take decisive action." The former is meant to capture those views consistent with ecological rationality and decisionmaking. Decisionmakers wish to bide their time, wait for additional information, or take limited, incremental steps to address the *possible* problem of climate change. They are open to the perhaps remote possibility that there may not, in fact, be a problem. But it is also consistent with the view that there is a problem and they want to acquire additional knowledge prior to making dramatic policy changes. It is also consistent with the view that even though the problem of climate change is indeed serious, too rapid and dramatic a response may be too expensive and disruptive to the economy to be justified. This is H_0, or the null hypothesis. The null hypothesis in this decision analysis is consistent with the belief in Heimann (1993) that the mission should be aborted. Since the implications of acting or not acting are different in two scenarios, and to maintain consistency with the original set-up in Figure 1, the axes are rotated with the actual decision sets being placed on the horizontal axis.[3]

The alternative "take decisive action" is consistent with the constructivist position on climate change. It reflects high levels of confidence in the climatological models that indicate substantial long-term damage from climate change, and reflects the view that only decisive action can result in sufficient mitigation to limit harmful effects of global warming.

If the constructivists are correct in their assumptions and policy is consistent with their beliefs, we find ourselves in the lower right quadrant (IV). If the ecological approach is correct and policy is consistent with that choice, we find ourselves in the upper left quadrant (I). However, if the constructivist position is wrong and their policy is followed, we move to the upper right quadrant (II), indicating a Type I error. As for the ecological approach, when policymakers decide not to act and are wrong, they locate in the lower left quadrant (III), representing a Type II error. Policy failure in the constructivist case reflects an error of commission brought about by the belief, possibly incorrect, that their simulation models of climatological change offer what amounts to sufficient levels of confidence in their predictions that the various possible outcomes can be viewed as a *risk* outcome, rather than accepting that the set of all possible outcomes is *uncertain*. Thus, they establish a large confidence interval and are willing to accept a low significance level (e.g., $p = 0.05$ or 0.01) for their rejection of the null hypothesis.

The failure of the ecological approach results from an error of omission brought about by the refusal to accept the threat assessment of the simulation models that establish a relatively narrow confidence interval band, which creates significance testing levels that are substantially greater than $p = 0.05$ or $p = 0.01$, leading to a refusal to reject the null hypothesis.

In sum, the ecological approach fails due to a Type II error (accepting the null hypothesis when it is false), which means

[3]Those who refer to Heimann's article might be confused by the fact his null hypothesis is that action should be taken—that is, the space shuttle mission aborted. Here, the null hypothesis is stated that no action or incremental action should initially be taken in dealing with climate change. In both cases, the administratively "conservative" approach is chosen.

believing that the available data for decisionmaking are too *uncertain* from a Knightian perspective to commit substantial resources or commit to irrevocable courses of action in seeking to mitigate climate change. In contrast, the constructivist approach fails due to a Type I error (rejecting the null hypothesis when it is true), which means conferring a greater sense of confidence in the predictions of the model than are warranted.

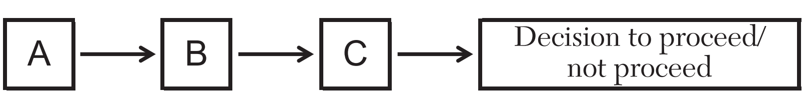
The Relevance of Serial and Parallel Processing to Our Argument

We now discuss one final aspect of our argument that provides useful insights into the decisionmaking process. While there are aspects of Heimann's (1993) work that go beyond the purposes of this article, he does show that whether one is concerned about Type I or Type II errors is intimately related to types of administrative systems. For our purposes, administrative systems merely represent a means of making decisions based on existing information.

Serial Systems

Serial systems are characterized by a structure that requires each "unit" to acquiesce before the system as a whole can act. It is important to note that the version of seriality shown here, where there is a sequence of decision points, is the traditional version of seriality. Another version, independent seriality, allows all relevant administrative units to simultaneously exercise their authority (Heimann 1993: 424). However, all must still "sign off" in order for a policy to move forward. Any one unit has a veto over any particular decision. A simple, traditional version of a serial system is shown in Figure 3. Here, the decision to proceed with some action means a policy must be agreed to by units A, B, and C. If A vetoes the decision, the process halts.

FIGURE 3
A Serial System



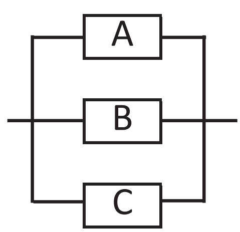
Parallel Systems

Parallel systems allow for an action or policy to pass through the system even if one or more units reject the policy. A simple parallel system is shown in Figure 4. Even if A vetoes the policy, it can be implemented if B and/or C (depending on the rules) act affirmatively. It is not surprising that parallel systems are so often favored over serial systems. Parallel systems offer the opportunity to implement needed policies quickly, in the face of potentially rapid changes in the organizational environment. And, as Heimann (1993) shows, under conditions whereby there are only two states—a correct or incorrect decision—parallel systems are more likely to yield the wrong policy.

A Three-State World

Heimann (1993) shows, however that, in a three-state world in which one is concerned about committing either a Type I or Type II error (and where the third state is the correct decision), serial systems are superior because they *reduce* the likelihood of Type I errors—that is, rejecting the null hypothesis when it is actually correct (acting when no action is necessary or desirable). [4] In contrast, in a three-state world parallel configurations tend to *increase* the probability of Type I errors while significantly reducing the probability of Type II errors, thus proving less reliable from the

FIGURE 4
A Parallel System



[4]In Heimann's study it is true that the costs of committing a Type II error (aborting the shuttle launch when it should have been allowed to proceed) would have been far less than the costs of committing a Type I error, which is what occurred. We cannot say with certainty in our case whether a Type I or II error is to be preferred. As we have already acknowledged, the uncertainty associated with both are subjective. In our view, the probability of adverse consequences resulting from either are relatively equally distributed.

long-run perspective because the correct decision is still the third option.[5]

Relation to Constructivist and Ecological Approaches

This brings us to the crux of our argument: serial processing and parallel processing systems can be thought of as organizational analogs to the types of decisionmaking defined earlier—that is, the constructivist and the ecological approaches. Specifically, serial processing systems are consistent with ecological types of decisionmaking, while parallel processing is consistent with constructivist thinking. Serial processing implies that knowledge is tentative and contingent, and that we function in a world of deep uncertainty (in a Knightian sense). We want to avoid irrevocable errors, which in our example is committing without equivocation to a set of policies that, once initiated, would be extraordinarily difficult to reverse. Serial processing is ideal in those situations in which we assume bounded rationality and relatively high uncertainty. Parallel processing, by contrast, works if we are quite sure we are not committing a Type I error. In other words, it makes the basic assumptions consistent with constructivist thinking including confidence in the information available and confidence in the ability of models based on that information to predict the future.[6]

A serial processing system can be viewed as a kind of crude proxy for aspects of the U.S. political system, with its separation of power and checks and balances, and with the rise of political parties and divided government. It is a system that promotes incrementalism, and guards against taking major policy actions that may be wrong, and that once initiated, are difficult to reverse. Conversely, our system is not constructed in a way that necessarily allows for rapid policy responses precisely when they might be needed. Our system has a predisposition toward the prevention of Type I errors.[7] Indeed, it

[5]For a detailed mathematical derivation of the probabilities of Type I and Type II errors for serial and parallel systems in two-state and three-state worlds, see Heimann (1993: 425–27).

[6]A self-consciously designed decisionmaking-administrative system might seek to build some limited degree of parallelism into more ecologically structured frameworks, while some seriality might be built into systems more prone to constructivist arrangements. This might help mitigate the more negative features of each.

[7]This is not to say there is not some degree of parallelism built into U.S. decisionmaking structures. The United States could more precisely be described as a hybrid.

can be viewed as a decision structure that puts a premium on the recognition that knowledge is contingent, evolutionary, and tentative.

Conclusion

This article has sought to addresses four important questions:

1. What framework helps us understand why policies succeed or fail?
2. How do different approaches to rationality and decisionmaking play a role in policy formation?
3. What relevance do Knightian concepts of risk and uncertainty have in providing an integrated theoretical framework that provides a richer understanding of (1) and (2)?
4. How does discussion of (1), (2), and (3) relate to the question of serial versus parallel organizational styles and its relevance for our broader discussion?

Following Heimann (1993), we can conceptualize many policy decisions in a binary choice situation as constituting a basic hypothesis-testing model. Incorporating competing versions of rationality and decisionmaking, as per Smith (2003), provides important insights into the possible choices made by decisionmakers. When viewed through the Knightian lens, it is easy to observe the strikingly different preferences of policymakers and the role of probability, risk, and uncertainty.

As applied to our case study of climate change, we show how different versions of rationality and decisionmaking produce different decisions and, most important, different types of errors, and that those errors can be better understood by incorporating Knightian risk and uncertainty. Constructivist decisionmaking, when wrong, results from excessive confidence in the deductive models of reality on which they rely. The belief that it is possible to strictly quantify threats leads to thinking that the various probabilities reflect risk events rather than uncertainty. Using the constructivist approach to formulate climate policy increases the likelihood of committing a Type I error. In contrast, ecological rationality and decisionmaking, when incorrect, produce a Type II error. The Type II errors of ecological rationality result when policymakers do not accept that anything approaching strict probabilities of threats can be determined, leading to high levels of uncertainty on their part, and thus a failure to act. Therefore, with climate change, constructivists commit errors of commission and ecological rationalists commit errors of omission. We also show that ecological approaches to decisionmaking are highly consistent with serial systems, as opposed to parallel processing structures. Finally, in conditions where we want to take into account multiple states (i.e., we are concerned with both Type I and Type II errors), serial structures are superior.

Given the forgoing observations, is it possible to know which approach to policymaking is to be preferred? That's a difficult question and depends on many variables. We hope, however, that our integrated approach will help advance thinking in this area. Certainly, one can point to other examples besides climate change policy that our theoretical approach could help clarify. Smith (2003), for instance, points to the constructivist approach to California deregulation in the early 2000s as a case of deductive, top-down policymaking gone awry, based on a host of faulty assumptions. One could also argue that the risk models of large financial institutions used similarly flawed logic.[8] Again, confidence in the predictive power of simulation models leads to excessive confidence in the ability to predict future events. In other words, financial decisionmakers thought they knew the likelihood of certain events occurring—believing they lived in a world of *risk* when in fact they lived in a world of *uncertainty*. It is hard to deny that in these cases, an ecological approach to decisionmaking combined with some form of serial administrative structures might have prevented disastrous mistakes from being made.

None of this is to suggest that one particular type of decisionmaking is innately superior to another under all circumstances, although the ecological approach offers important advantages when policymakers have time to "test the waters" and observe events prior to making irrevocable commitments. Where that advantage does not exist, constructivist approaches may be preferable and the only viable ones. Finally, whether constructivist or ecological approaches to

[8]The risk models used by financial institutions were not imposed through statute and regulatory authorities. However, our point here is that political decisionmakers including regulatory authorities did not act to alter the use of such models, in part because they accepted the validity of those models. As Roubini and Mihm (2010: 59–60) note, "An almost religious faith in models helped create the conditions for the [financial] crisis in the first place, blinding traders and market players to the very real risks that had been accumulating for years."

decisionmaking are preferred depends on the question of whether the costs of being wrong can be absorbed. If the cost of acting is "not that high" then a constructivist approach may be preferable. Otherwise, an ecological strategy may be the default.

References

Caldeira, K., and Wood, L. (2008) "Global and Arctic Climate Engineering: Numerical Model Studies." *Philosophical Transactions of the Royal Society* 366 (1882): 4039–56.

Gore, A. (2007) *The Assault on Reason.* New York: Penguin.

Hall, J. (2007) "Probabalistic Climate Scenarios May Misrepresent Uncertainty and Lead to Bad Adaptation Decisions." *Hydrological Processes* 21: 1127–29.

Hall, J.; Fu, G.; and Lawry, J. (2007) "Imprecise Probabilities of Climate Change: Aggregation of Fuzzy Scenarios and Model Uncertainties." *Climatic Science* 81: 265–81.

Heimann, C. (1993) "Understanding the Challenger Disaster: Organizational Structure and the Design of Reliable Systems." *American Political Science Review* 87 (2): 421–35.

Jackson, R. B., and Salzman, J. (2010) "Pursuing Geoengineering for Atmospheric Restoration." *Issues in Science and Technology* 26 (4): 67–76.

Jarvis, D. S. L. (2008) *Theorizing Risk and Uncertainty in Social Enquiry: Exploring the Contributions of Frank Knight.* Research Paper Series: LKYSPP08-001, National University of Singapore.

Knight, F. (1921) *Risk, Uncertainty and Profit.* Boston: Hart, Schaffner & Marx.

Landau, M. (1969) "Redundancy, Rationality and the Problem of Duplication and Overlap." *Public Administration Review* 29 (4): 346–58.

Nordhaus, W. D. (2007) "A Review of the Stern Review on the Economics of Climate Change." *Journal of Economic Literature* 45: 686–702.

__________ (2008) *A Question of Balance: Weighing the Options on Global Warming Policies.* New Haven, Conn.: Yale University Press.

Perrow, C. (1984) *Normal Accidents: Living with High-Risk Technologies.* New York: Basic Books.

Raines, J. P., and Jung, C. R. (1992) "Schumpeter and Knight on Economic and Political Rationality: A Comparative Restatement." *Journal of Socio-Economics* 21 (2): 109–24.

Riker, W. H. (1988) *Liberalism against Populism: A Confrontation between the Theory of Democracy and the Theory of Social Choice.* Long Grove, Ill.: Waveland Press.

Roubini, N., and Mihm, S. (2010) *Crisis Economics: A Crash Course in the Future of Finance.* New York: Penguin.

Singer, F. S. (1997) *Hot Talk, Cold Science.* Oakland, Calif.: The Independent Institute.

Smith, V. (2003) "Constructivist and Ecological Rationality in Economics." *American Economic Review* 93: 465–508.

Stern, N. (2007) *The Economics of Climate Change: The Stern Review.* Cambridge: Cambridge University Press.

Tol, R. S. J. (1995) "The Damage Costs of Climate Change: Towards More Comprehensive Calculations." *Environmental and Resource Economics* 5: 353–74.

Vaughan, D. (1997) *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA.* Vol. 1. Chicago: University of Chicago Press.