CHAPTER 6

Strategy in the Face of Uncertainty and Unpredictability: The Research University Role

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UNCERTAINTY, RISK AND POLICY-MAKING

One of the most vexing problems we face today in moving toward a more sustainable society is the problem of uncertainty and imperfect predictability of complex physical and biological phenomena. Such states of knowledge cause havoc when scientific and technological knowledge, projections and predictions feed into social and political decision-making systems. It appears that democratic systems have particular difficulty dealing with strategic issues to begin with, and these difficulties are greatly compounded when the forcing functions that need to be recognized by strategies have nontrivial uncertainty. This may not be strictly inherent in democracy, because there are democracies, especially in Europe, that seem to have dealt better with such uncertainties than has the United States. Nonetheless, decision-making is much more difficult when it must be based on factors that are not deterministic and predictable.

The most obvious example, which is directly associated with our theme of sustainability, is the role of human activity in disrupting the stability of the earth's climate. But this is not the only such area of concern. It also appears in consideration of humankind's ability to rapidly alter biological processes, as in the case of genetically modified foods. It even arises in the context of selecting treatment options for various human diseases.

Although the theme here is *uncertainty*, one is quickly drawn into the related concept of *risk*.

In seeking certainty, we are trying to answer some seemingly simple questions:

- What will happen?
- Where will it happen?
- When will it happen?
- Why will it happen?
- What will be the consequence of it happening?

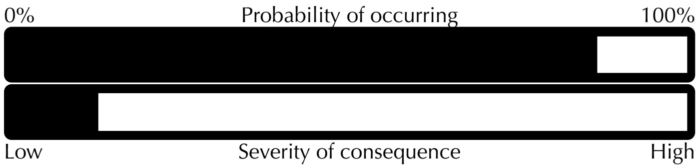
If I throw a rock at a tin can sitting on a wall, assuming I have good aim, I know from experience more or less what will happen. And indeed, if a scientist knows the initial conditions and physical parameters of the rock, the can, etc., and applies Newton's Laws, he or she can predict exactly what will happen, where it will happen, when it will happen, why it will happen and what the physical consequences will be.

What most citizens know about scientific and technical matters is based explicitly or implicitly on such classical deterministic science as Newton's laws of motion. Whether we formally learn such science or simply build intuition through experience, most of us have a mindset that if we do A, then B will predictably follow, and C will be the consequence. Furthermore, citizens think of science and engineering as producing deterministic knowledge or predictable devices. If a scientist is asked a question, we expect an answer that we can count on. Ask an engineer how a device will react to a certain input, and we expect an equally clear answer.

Unfortunately, many of the phenomena we need to consider today are not inherently certain, and to make matters worse, we usually have incomplete information to begin with. Ask a scientist whether it will rain in a certain location tomorrow and she will only be able to assign an approximate probability to the importance of you carrying an umbrella. This is largely because of complexity and insufficient data. Interestingly, many human-made devices are now so complex that engineers cannot always predict their responses with full certainty either. In both cases, the public and policy-makers probably feel that the scientists and engineers have let them down, or that they do not know what they are talking about.

To navigate the shoals of uncertainty regarding phenomena that can have bad consequences, we apply *risk analysis*. Basically, this means that we attempt through modelling, simulation or analysis of historical data to describe the probabilities of various outcomes and then to connect them to the consequences of those possible outcomes. This may apply to engineered devices or systems, e.g. a nuclear power plant; or it may apply to natural biological systems such as a disease. Decision-makers, such as government officials or business leaders, usually think about these matters in a way that can be made explicit by simple slider bars (Ropeik & Gray, 2002). Ropeik and Gray introduce two slider bars representing the probability of occurrence and the severity of the consequence of that occurrence:

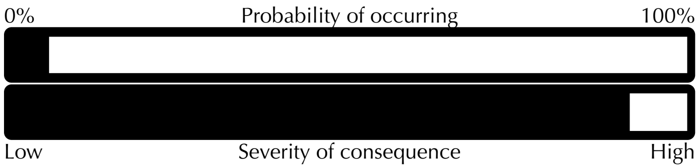
Figure 1: Slider bar to display risk (high probability, low consequence)



This clearly represents the way most of us think about risk. The event that is shown above has a rather high probability of occurring, but its negative consequence is fairly low. For example, the weather prediction may be an 85% chance of rain, but if you walk to work without your umbrella, the chance that you will be significantly damaged by getting wet is very small.

The situation that causes more consternation is one that has a very low probability of occurrence but has potentially disastrous consequences.

Figure 2: Slider bar to display risk (low probability, high consequence)



The probability that an earthquake of magnitude 9.0 would occur with an epicentre near Fukushima Japan was undoubtedly very low, and the probability that it would launch a tsunami with a wall of water 128 ft high (39 metres) was even lower, yet the consequences were horrible when both events actually occurred simultaneously on 11 March 2011. As a consequence, approximately 25,000 people died. In addition, a complex of nuclear power plants and their spent fuel repositories were seriously affected, causing great physical damage and small leaks of radiation. Furthermore, the economic, psychological and even political consequences were very large.

Whether or not policy-makers and business leaders make the right decisions regarding such low-probability/severe-consequence scenarios, most of them would readily understand this discussion and see it as the starting point for decision-making or regulation. Why? Because events such as earthquakes and tsunamis are understood to be natural physical phenomena that occur from time to time and they know experientially that the force of nature can be enormous. They do not expect scientists to be able to predict these occurrences accurately, especially well in advance. Furthermore, the occurrence of an earthquake and the launching of a tsunami are understood to be relatively *straightforward* physical phenomena, in the sense that they have occurred many times before and to some extent their causes can be explained.

Global warming and climate change, on the other hand, are far more complex. Their prediction is inherently probabilistic. Even our understanding of the past and present is incomplete and statistical. Indeed, a key finding of the recently released U.S. National Research Council report (National Research Council, 2011) is stated as follows:

The ***preponderance*** *of the scientific evidence* ***points to*** *human activity — especially the release of* CO_2 *and other heat-trapping greenhouse gases (GHGs) into the atmosphere — as the* ***most likely*** *cause for* ***most*** *of the global warming that has occurred in the last 50 years* ***or so****. [Underlining mine.]*

Climate change depends on nonlinear interactions of many subsystems of the climate and on various forcing functions that are complicated to understand. The impact of human activities on global warming was scientifically controversial in the early years of studying this phenomenon because our understanding was largely based on computer modelling with insufficiently fine computational grids and on a large number of simplifying assumptions and sub-models. Most of all, however, the long time scales involved and the nonlinearity of the phenomena make it really hard to for many people to relate to.

In order to move toward consideration of roles universities might play in improving understanding and policy in support of sustainability, we might benefit from examining a few cases of past reaction to global challenges.

CFCs and the Ozone Layer: Getting it Right in the Face of "Certainty"

In the 1970s, scientists determined that depletion of the stratospheric ozone layer due to widespread human use of chlorofluorocarbons (CFCs) was a threat to life on earth. The trace gas ozone that resides in the stratosphere establishes one of the many delicate balances that make life possible, because in its natural state it protects organic life, including human beings, from harmful levels of ultraviolet radiation.

CFCs were developed in the 1930s and were considered to be *wonder chemicals* because they are nontoxic, noncorrosive, nonflammable and very useful, e.g. as refrigerants, as propellants in pressure cans, and in the production of

Styrofoam. But in 1973, Molina and Rowland hypothesized a complex chemical process by which man-made CFCs were depleting stratospheric ozone (Molina & Rowland, 1974). Considerable controversy ensued in government and industry circles that was not unlike that surrounding global climate change today. In 1977, the United Nations Environmental Programme (UNEP) established a Coordinating Commission on the Ozone Layer.

In 1978 CFC spray cans were banned in the U.S. and in Scandinavian countries. In 1985, the UNEP *Vienna Convention on the Protection of the Ozone Layer* was signed. This convention pledged several countries to cooperate on research into the effects of CFCs and into alternative industrial and consumer technologies. They further agreed to cooperate on legal and policy matters and in facilitating the development of knowledge and the transfer of relevant technologies to industry.

In 1987, 24 countries signed the *Montreal Protocol on Substances that Deplete the Ozone Layer*. This now famous international protocol froze consumption of key CFCs at 1986 levels, and committed the signing countries to reduce consumption by 50% within ten years. Importantly, developing countries were given an additional grace period before they were required to phase out the use of CFCs. Interestingly, once the process got rolling, worldwide CFC consumption was phased out far more rapidly than was committed to in the protocol.

The story of CFCs and the Ozone Layer as outlined above seems remarkably smooth, certainly as compared with climate change matters in the present era. But to an extent, this is misleading. There were plenty of rocks along the road. There were loud political arguments and some countries were adamantly opposed to the phase-out in the early stages of discussion. So why was the plan successful on a reasonably short time frame?

I think that the relationship of CFCs to ozone depletion and the fact of major depletion were more or less considered as "certainties". The ozone hole above the South Pole was graphically and dramatically presented in satellite images for all to see. Although the science was still considered to be speculative during the negotiations of the Montreal Protocol, in due course scientists at DuPont and other companies that had manufactured most of the CFCs studied the science thoroughly and concluded that Molina, Rowland and others were correct.

Nonetheless, the global community, with deep engagement by scientists and leadership of the United Nations came to grips with a complex environmental threat of global dimension that would play out over the long residence time of the relevant chemicals in the stratosphere.

Industry coming proactively on board once the science became clear would seem to be an important factor, and perhaps *the* key factor, in the successful phasing out of CFCs. The immediate economic consequences, while certainly not trivial, were much smaller than those posited in the current debates about global climate disruption. It undoubtedly was extremely relevant that industrial chemists developed economical alternatives to CFCs.

A different, though pertinent, example comes from the rapid advance of life science a few decades ago.

Recombinant DNA Safeguards: Getting It Right in the Face of Uncertainty

In the early 1970s, the public read in the newspapers and heard on radio and television that scientists had developed something called *recombinant DNA technology*. This involved transplanting genes from one species into the cells of a different species. The ability to do this emerged rather rapidly in the late 1960s and early 1970s from several laboratories across the U.S. and Europe. The public, and indeed many scientists, worried that application of this new technology might pose fundamental risks to life on our planet.

Although the immediate consequences of such gene transplantation were well understood by biologists and molecular chemists, there was deep concern that unforeseen negative consequences for health and the environment might be on the horizon. For example, rapidly propagating diseases with no known treatments might inadvertently be launched, or newly created modified organisms might interact with other organisms in ways that had unpredicted, dire consequences.

These concerns were very deep among much of the lay public and were made even stronger by those who saw it primarily as a moral issue. Leaders of the biology community took these concerns about unpredictable consequences seriously; indeed a few of the scientists held these worries themselves. The key group of scientists engaged in recombinant DNA research was fairly small by today's standards, and after discussion they decided in 1974 to establish a voluntary moratorium on certain recombinant DNA work. They then decided to convene a conference to discuss the issues with other scientists and concerned parties.

This conference was held at Asilomar, California, in February 1975. There were 140 participants. Most were scientists, but physicians, lawyers, government officials, journalists, philosophers and religious leaders also participated. The purpose of the conference was to decide whether to lift the moratorium and, if so, to define the conditions for safely conducting recombinant DNA research.

The group assembled at Asilomar came to a strong, though not unanimous, consensus that the moratorium should be lifted; however, they also spelled out in some detail strict biosafety guidelines for safely conducting such work. These specifications for research facilities and procedures were subsequently adopted by the U.S. National Institutes of Health (NIH) and ultimately in many other countries as well.

So here we have an example of explicitly coming to grips with a type of scientific uncertainty. The leaders of the scientific community drove this solution through a nongovernmental consensus process. It appears to have been successful. It led directly to subsequent governmental regulation, and it engendered considerable public trust. Nonetheless, it should be noted that some have criticized this process for having given insufficient weight to ethical and legal discussion and for failure to consider in depth implications for biological warfare.

In my view, the temporary, self-imposed moratorium on recombinant DNA research and the deliberations of the subsequent Asilomar Conference comprise a high point in setting policy and strategy in the face of uncertainties that might hold serious, negative consequences for life on earth. However, it was simple to deal with in the sense that the solution involved straightforward technology and protocols for containment of any biohazards that might occur. Furthermore, only highly trained scientists and technicians in small facilities conducted the work involved.

Nonetheless, it is an instance of us having "gotten it right".

GLOBAL CLIMATE DISRUPTION: GETTING IT WRONG?

A Complex, Nonlinear, Probabilistic Phenomenon

As we think about moving aggressively toward a more sustainable global society in the face of rapid development in large populations and an inexorable march toward a world population of nine billion people, the world's inability to take action against climate change is a major problem. The poster child for paralysis in this regard is the United States, although they are joined in it by many other countries. What keeps the U.S., and perhaps other countries, from setting a firm course in the face of enormous risk to life on earth in the context of considerable real or apparent uncertainty?

There seems to be a clue to the problem in the use of language. Both politicians and scientists discuss whether or not they *believe* that climate change is real and if so, whether or not they *believe* that it is caused in large measure by human actions. In far too much of the discourse in the U.S., *belief* has taken on a connotation of a religious-like or ideological belief, rather than implying whether or not scientific observation and analysis are sufficient to form a basis for policy.

Climate science is complex because the earth's environment and energy systems are complicated and held in delicate balance. Climate science is not easily reduced to a few simple observations and explanations immediately

Figure 3: Notional immediate, linear response to an action: Easy to understand

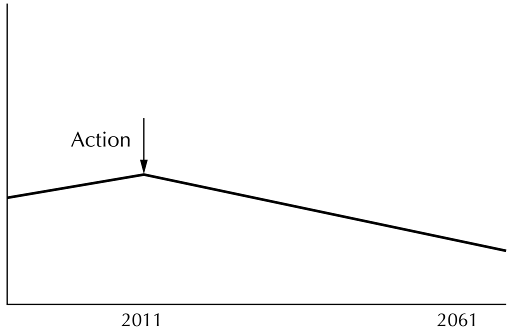
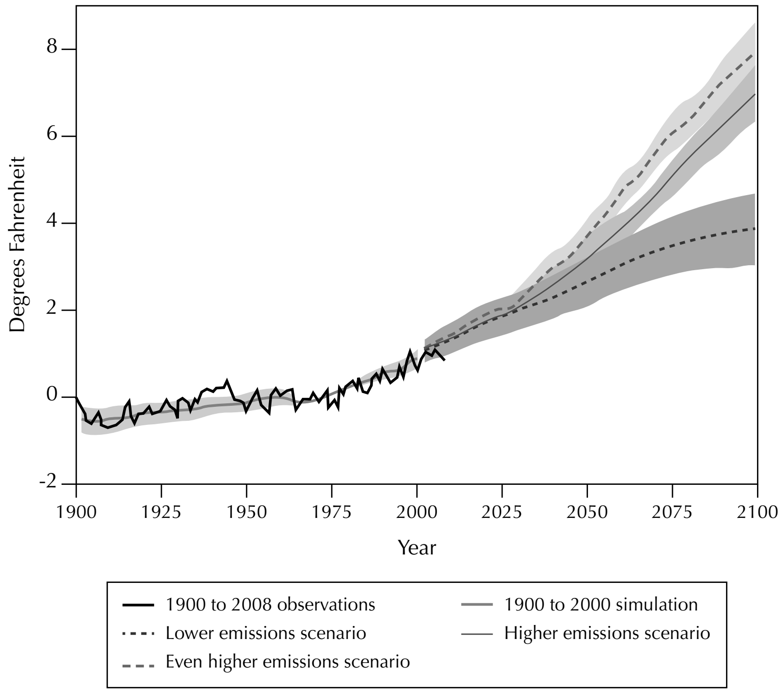


Figure 4: Nonlinear, Delayed Response: Not So Easy to Understand



Source: National Research Council, 2011. Figure 2.4, p. 22.

accessible to lay persons. While images of polar bears on melting ice are dramatic, their significance is not crisp, static and obvious in the same sense as were the images of the ozone hole in the stratosphere. The analysis of what we face going forward is probabilistic in nature, and that is always a problem in public policy formulation. The time frame for major damage is not immediate. The necessary risk mitigation, however, requires near-term action to stem problems that would occur many years into the future. The nonlinearity, i.e. future acceleration of the processes, is a particularly vexing issue to put before the public and policy-makers who are used to thinking linearly.

Cultural Impediments and Mindset

Because we are dealing with our earth and its ability to sustain life, the mindsets and belief systems of individuals and groups frequently come into play. The very successful history of the United States is quite recent by world standards. Its narrative is one of a continual, individualistic, westward movement. The pioneers *tamed* nature and harvested bountiful crops, minerals, animal life and energy resources. The industrial age amplified this taming and harvesting to a massive scale. Resources were readily available. Nature provided. It is ingrained in our mindset.

Americans, based on experience, are predisposed to think of resources as limitless on the time scale of a human lifetime, and by extrapolation, much longer. For many, a religious belief system also underlies the way they think about long-term issues like climate change. Indeed, one Congressman who holds a key position with regard to national policy in energy and environment has stated that he does not believe that humans will be responsible for catastrophic climate change and cites the "infallible word of God" in the Bible's Book of Matthew as the source of his belief (Rudolf, 2010).

Another issue that arises clearly in America, and in a different guise in other nations, is a lack of true global view. Americans of previous generations, and even of my own generation, lived very insular lives. Except for the military experience of the World Wars and international travel by the wealthy, we lived very much apart from the rest of the world. A huge swathe of the American public lived in small, relatively self-sufficient towns and came to view the rest of the world as something exotic. Although America, its business, economy and culture are now highly integrated into the world, this reality remains at odds with the national narrative deep within the psyche of many citizens. So national interests are often seen apart from the interests existing in other countries.

In a not altogether different way, many in the developing world, who actually have an opportunity to build their infrastructure and economy in a more *green* manner, also seem to perceive their national interests to be independent of those of the rest of the world. They may believe that they are starting up the economic ladder from the bottom and have a right to develop, at least for a period, without carrying the additional costs of green technologies. This argument is understandable, and possibly one that could be accepted as valid if the developing nations were a small part of the world's population. But the fact is that they comprise a huge part of the world's population and the rapid industrialization of countries like China and India will soon dominate the world scene.

Many Americans and others in the developed world have been fortunate to have a comfortable life. These lives have been built by individuals or by the preceding generation, and they include mobility, physical comfort and access to a wide variety of food and products that make their lives enjoyable, but that use large amounts of energy and other resources. There is an understandable instinct that if the environment is to be improved, and if our climate is to be rendered more stable, they will have to give up these things, i.e. to make great sacrifices. Undoubtedly some sacrifice is required to achieve a more sustainable economy and lifestyle, but there are huge possibilities that through focused innovation we can dramatically lessen the actual *sacrifice* required. The most obvious case is that by increasing the efficiency of buildings, appliances and other systems that use large parts of our energy budget, we can realize very large reductions in emission of greenhouse gases and still live and work comfortably.

Finally, there seems to be a substantial part of the American population that believes that science and technological innovation will be able to conquer the challenges ahead to our environment and climate. This, we hope, is true; however, there must be a starting point, a strategy and a political will. An optimist can see the beginnings of such movement, especially in the viewpoint and passions of the younger generation. But somehow, the American "can do" spirit has not yet been tapped on a broad scale.

All of the factors discussed in this section lead to a tendency to say *mañana* and take slow action or no action. And if we add to this stew uncertainty and nonlinearity, two things happen. First, the danger of inaction or slow action is greatly amplified, as are the ultimate costs of coming to grips with climate change. Second, the necessary extent of action required, and its near-term and long-term economic consequences, are difficult to measure.

But there is one last thing that may be at work here: *scale*. In a recent interview on NPR (National Public Radio in the U.S.), *New York Times* columnist Nicholas Kristof discussed what he viewed as his failure to motivate the public to take action against the horrible human suffering in Darfur. He cited social science research that suggests that individuals tend to simply tune out information that seems to portray issues of a scale that they cannot really comprehend and intuitively do not believe they can impact. He described experiments in which a group of potential philanthropic donors were presented with an exposition of extreme hunger among 21 million people in West Africa. This group was subsequently solicited for contributions to aid these starving people, but they pledged almost no money for this purpose. A second group was shown a photo of a single starving girl from Mali. This group pledged very generous support. This suggests that it is human nature to turn away from problems of large scale with which we do not emotionally connect or think we cannot effectively confront as individuals. (Kristof, 2010)

So, among the factors that may be leading to a lack of political will in the U.S. and elsewhere to set serious strategies toward sustainability and toward combating global climate disruption are:

- Belief systems, including religion
- Complexity
- The American narrative of the preceding three centuries
- The "right" of developing nations to climb the economic ladder unencumbered by costs of sustainability
- Sacrifice
- Science and technology will solve it (without investment and political will)
- *Mañana*; it's in the distant future
- Being overwhelmed by scale.

When these factors are combined with uncertainty, risk and nonlinearity, it becomes quite difficult to achieve the breadth of understanding and commitment to develop the political will required in a democracy.

What Can Universities Do to Help?

In the face of these and other realities, what should the university community do? What should be our goals? Possible goals include:

- Reduce the uncertainty?
- Concentrate on understanding risk?
- Develop better social/political means of discussing uncertainty and risk?

Universities could play major roles in addressing all three of these possible goals.

It is in everyone's interest to reduce the uncertainty associated with phenomena associated with sustainability and especially climate change. Part of the political controversy about climate change stems from the fact that early discussions were indeed based on computer modelling that was restricted by the technology of the day to grid sizes and time steps that were really insufficient. More recently, the computational capabilities have improved dramatically, and much of the scientific evidence and understanding now come from direct *observation*. Of course, the nature of most scientific progress means moving down a path, usually an iterative one of observation, experimentation and simulation that continually reduce uncertainty. Even though our core understandings of climate change are now accepted as scientifically solid by most of the scientific community, continued work to reduce uncertainty in what we know and what we project forward in time remains an extremely important role for university researchers.

It certainly appears that movement toward a more sustainable future is one of many important domains in which democracies could make better decisions if citizens had a better, imbedded understanding of risk. They would also need to view risk assessment and cost-benefit ratios as natural elements of decision-making. All too frequently, the public and many policy-makers think of risk in a binary fashion. Things are either required to be absolutely free of risk, or else they are assumed to be unacceptably dangerous. This human instinct is fully understandable, but in a modern, complex society, we must do better. It seems to me that universities, in their research and education in the social sciences, could contribute greatly to understanding risk, understanding the cognitive responses to risk, and enhancing our ability to communicate effectively about risk. If society is handed more effective means of analysing, considering, communicating and utilizing risk as a more natural part of our discourse, wiser decisions might be made about areas such as sustainability and priority setting.

Uncertainty generally is well understood by people with education and training in science, medicine or engineering. But uncertainty of the type discussed here often is not handled well in public discourse and political decision-making. There may be a very productive role for the humanities and arts in ameliorating this. After all, the humanities largely evolve around understanding and communicating about deep human challenges, motivations and reactions, including the role of luck, complexity and human nature. Humanistic inquiry ranges over vast periods of time and from global truths to the narrowest spaces of human thought and motivation. Surely there is room here to contribute to our progress toward a more sustainable future. After all, in the first instance, sustainability is largely a mindset.

Similarly, the arts help us to understand big themes and the interplay of individuals and ideas with the larger society. Indeed, it is sometimes said that artists see the future before the rest of us. There should be a productive common cause of artists with scientists, engineers, economists, business scholars and others on our campuses for moving toward the understandings necessary to deal effectively with challenges like sustainability in the face of uncertainty.

SUMMARY

In summary, challenges like sustainability that must be addressed in the context of uncertainty, risk and complexity, are daunting because of many easily identified factors. These factors have their origin in history, belief systems, personal experience and the popular expectation of scientific certainty. There would seem to be very important roles for virtually every corner of research universities — natural science and engineering, social science, humanities and arts — to bring their research, scholarship, analysis and especially education to bear on the challenge of creating a citizenry, a policy community and political system better able to join together to move toward a more sustainable future in a context that is inherently uncertain.

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