The Limits of Knowledge and the Climate Change Debate

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> Those who have knowledge don't predict. Those who do predict don't have knowledge.
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> —Lao Tzu

> Doubt is not a pleasant condition, but certainty is absurd.
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> —Voltaire

The question of whether climate change is produced by anthropogenic global warming (henceforth AGW) has triggered an increasingly contentious confrontation over the conduct of science, the question of what constitutes scientific certainty, and the connection between science and policymaking. In a world in which we seek to understand complex, multifaceted phenomena such as

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Cato Journal, Vol. 36, No. 3 (Fall 2016).

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climate (and to extract from this knowledge appropriate policy responses) the enduring epistemological question arises: What do we know? Logical inquiry might be expected to help resolve this knowledge problem (Hayek 1945) but is confounded by the assertion that the "science is settled," by condemnation of those who disagree as "deniers," and even by proposals that they be prosecuted as RICO offenders.[1] There is increasing talk on the left—and even among Democratic state attorneys general and the highest levels of the Obama administration—of criminalizing the very effort to rebut the climate change orthodoxy (Gillis and Schwartz 2015, Moran 2016).

What could have been a fruitful, albeit perhaps contentious debate over decisionmaking when addressing highly complex phenomena has degenerated into a prolonged contest. While recognizing the problems attending denial of climate change, our purpose here is to elucidate the limitations of the now-dominant view. We ground this view within a Kuhnian framework and suggest the limitations of that framework in understanding the uncertainties of climate change and policies that flow from it. Kuhn (1962) points to an often-repeated process whereby scientific paradigms become locked in and resist challenges to their validity because knowledge production is socially controlled and deeply

[1]The term "denier" seems to encompass a wide range of possible positions on global warming and climate change. It clearly includes not just those who reject altogether the idea that the planet is warming, or that it is warming as a result of greenhouse gas emissions. "Denier" also is used promiscuously to describe those who express even mild doubt or who offer certain qualifications about what may be occurring. Most important, the usage of "denier" appears to conflate these positions with the question of how, assuming anthropogenic global warming exists, we should address the problem. On this point, the possible approaches range from those of Lord Stern (2013) and Martin Weitzman (2007, 2009), who believe that dramatic action needs to be taken immediately, to those of Nordhaus (2007, 2008), who has suggested a more incremental approach. It is worth noting that even among those calling for dramatic action, there are major distinctions to be made between those who believe that catastrophic climate change is virtually certain, and those believe it is unlikely but that the precautionary principle nevertheless calls for addressing the problem through dramatic policy interventions.

invested in the political currents of the day.[2] Power relationships and vested interests have frequently played a critical role in determining what acceptable science is or is not. In contemporary parlance there is historical lock-in and path dependence: once there is commitment to a particular body of knowledge that relates to a particular course of action, the costs of change increase over time and even if one wishes to move to a different path, it is difficult to do so. This is not to say that it is impossible for dissenters from the standard accepted approach to get their views expressed in the standard academic journals, but it is clearly more difficult. Moreover, consistent with the concept of path dependency (Greif and Laitin 2004, Arthur 1989), once a scientific paradigm becomes locked in, it becomes increasingly difficult to challenge the status quo in the accepted scientific outlets, at least until challenges to the orthodoxy of the day become so compelling they cannot be ignored.

To be sure, sometimes change does take place in a relatively smooth fashion, as when Lavoisier's description of oxygen led to the abandonment of Becher's phlogiston theory of combustion. At other times, where long-held doctrine is at stake, the conflict over new ideas becomes brutal: Galileo was tried by the Inquisition, found guilty, and spent the rest of his life under house arrest. In all cases, time is involved and supporting facts must be provided before a new paradigm gains acceptance. Both Wegener's 1915 theory of continental drift and Milankovitch's 1912 theory of the relationship of climate cycles to earth-sun geometry were dismissed for many decades until new evidence was provided—the Wilson-Morgan-Le Pinchon-McKenzie evidence for plate tectonics that was codified in 1965–67 and the Hays-Imbrie-Schackleton spectral analysis of ice core data that reinforced the idea of orbital forcing in 1976 (Hays, Imbrie, and Shackleton 1976).

[2]As noted by an anonymous reviewer, discussion of climate change takes place to a considerable extent within the so-called "blogosphere." While there is no formal peer review process in that setting, there is nonetheless an informal sorting of viable versus nonviable ideas and theories. Given the resistance, consistent with Kuhnian processes involving the social construction of scientific theories, to research challenging the established scientific position, those who differ from the scientific orthodoxy often find these nonstandard means of communicating ideas very valuable.

Emergence of the AGW Paradigm

AGW theory is an example of a contemporary Kuhnian lock-in. How and why did it emerge? According to Lindzen (1992) it has its origins in the observation that CO_2 levels are increasing in the atmosphere due to the burning of fossil fuels, and that CO_2 increases are not simply correlated with rising global temperatures, but are forcing agents. Thus in Mann's view (Mann, Bradley, and Hughes 1998) the post-1970 surge of global growth has created a "hockey stick" of increased emissions, higher CO_2 levels, and therefore temperatures. The mechanism is that of the "greenhouse effect." CO_2 is one of several greenhouse gases—methane is another—that inhibit the radiation of heat from the earth's surface back to space: hence AGW. The abrupt increase in temperature supposedly captured by Mann's hockey stick led invariably to the conclusion that there was greenhouse warming, that humans were the cause, and that dramatic intervention was required to prevent runaway global warming in the future.[3]

This now-standard narrative, consistent with the Kuhnian vision of "normal science" as a social construct, can be seen in the emerging scientific debate over just when the Anthropocene Epoch began and humans achieved the ability to alter the nature of the environment. Most believers in AGW make the case that the Anthropocene began with the Industrial Revolution in the late 18th century (Crutzen 2002), with gradual increases in greenhouse gas emissions culminating in the sharp temperature increase portrayed in Mann's "hockey stick." Certainly, that narrative fits the needs of this camp. But there

[3]It is worth noting that 60 years ago many climatologists suggested that Earth was entering a new ice age, the consequences of which would have been profound for food production and its impact on human settlements and migration (Hays, Imbrie, and Shackleton 1976). At the same time, neo-Malthusians such as Ehrlich (1968) proclaimed that Earth was on a disastrous trajectory because global population was rapidly outstripping food supplies. Such predictions warned of disastrous food shortages in advanced industrial societies, and mass starvation elsewhere. Ehrlich's doomsaying struck a responsive chord with the intellectual elites of the day and helped spawn massive and draconian efforts at population control. Of course, Ehrlich's predictions proved laughably false. The Green Revolution and its progeny, as well as the amazing advances made with genetically modified crops, have led to massive increases in food production. Today, with a population more than double what it was when Ehrlich first came on the scene, the food supply situation is much better than it was. The new environmentalist mantra is that the revolution in food production is threatened by global warming.

are other narratives that may be at least as compelling and could have resulted in an alternative lock-in to a different view of global warming. Some contend that the Anthropocene began thousands of years ago with the transition from hunter-gatherer to agricultural societies (Glikson 2013, Ruddiman 2013, Balter 2013).

Researchers like Loyola (2016) evaluate the anthropogenic nature of greenhouse gas warming within the context of even longer cycles of hundreds of thousands of years marked by periods of warming that could not have been triggered by human activity. More immediately, others suggest that a date around 1610, or alternatively, 1964, should be considered the beginning (Lewis and Maslin 2015). In the latter case, advocates point to the effects of atmospheric nuclear testing and the Nuclear Test Ban Treaty that was signed in 1963 (Waters et al. 2014; also see Lewis and Maslin 2015). As for the earlier date, Nevle and Bird (2008) point to the dramatic Columbian discovery of the Americas and the resulting integration of economies that led to the collapse of indigenous civilizations by the early 1600s. European expansion resulted in a drastic decline in population, producing a noticeable drop in greenhouse gas emissions that only recovered decades later (also see Lewis and Maslin 2015).

The point here is that choosing one date or another produces a lens through which we view scientific observations. If humans were shaping the environment and engaging in activities contributing to AGW, or reducing AGW as in the case of the Columbian intervention, then the way we interpret our influence today on the climate must surely be altered. An early date leads to human impacts on climate being seen as being part of the natural order (Lewis and Maslin 2015), while a much later date produces a narrative that sees those activities that result in climate change as a violation of a pristine nature, which must be rectified by any means necessary. Today, the "consensus" notion is that the Anthropocene is a late arrival, and this fundamentally frames the debate.

The Role of Environmental Advocacy

AGW theory developed in the 1980s in lockstep with growth in environmental advocacy. In Europe, militant new Green parties emerged, committed to forestalling what they believed to be an apocalyptic crisis. In the United States large public interest advocacy groups began to use "global warming" as a fundraising instrument

and to funnel money to the climate modeling community. Money talked. "By early 1989, the popular media in Europe and the United States were declaring that 'all scientists' agreed that warming was real and catastrophic in its potential" (Lindzen 1992: 92). Although there were skeptics, they were becoming marginalized—sidelined in Senate hearings, having papers rejected by scientific journals, being denigrated in popular publications, and excluded from the activities of the Intergovernmental Panel on Climate Change (IPCC).

At this stage a firm marriage emerged between environmentalism and left-liberal parties' dreams of sustainable egalitarian societies based on suppression of economic growth in favor of smaller populations, and relying to the maximum extent possible on renewables. Global warming also became a major concern for national security agencies, which further increased funding for climate modelers and drew increasing proportions of academia into a position of AGW dependence for their research support. Growing numbers of scientists, with eyes focused on their research budgets and livelihoods, were willing to sign on to the proposition that "the science is settled"—even to sign letters calling for the prosecution of skeptics, Inquisition style.[4] To name just one instance among many, when the ecologist James Steele offered a rebuttal to the claims of a butterfly ecologist, Camille Parmesan (Parmesan 1996), that blamed climate change for threatening the Edith's checkerspot butterfly with extinction, he was immediately attacked as a "denier" (Ridley 2015a). An insidious kind of policy-based evidence-making is taking place: as Plimer (2015: 10–11) suggests, it is based on "pre-ordained conclusion, huge bodies of evidence are ignored and analytical procedures are treated as evidence."

[4]The most notorious such communication was a letter from Jagadish Shukla (the lead signatory), a climatologist at George Mason University; Edward Maibach, a professor of communications, also at George Mason; and 18 others dated September 1, 2015 (Richardson 2016). In this letter the authors urge the Obama administration to consider prosecuting, under RICO (Racketeering Influenced and Corrupt Organizations Act), corporations and other organizations that have "knowingly deceived the American people about the risks of climate change. . . ." Later, in response to a lawsuit brought by the Competitive Enterprise Institute (CEI), the main authors sought to keep their email exchanges from those challenging the letter. That effort failed when the CEI obtained a ruling from a federal court under the Freedom of Information Act requiring George Mason University to release the e-mails (Shukla et al. 2015). Sadly, the difficulty one would have in finding significant mainstream news coverage of these events parallels the difficulty that scientific dissenters have in publishing findings in academic journals.

A Poisoned Debate

Money aside, it may be worth considering why the arguments over climate change have become as vitriolic as they are. On the one hand, if one acknowledges the reality that climate constitutes a system consisting of interacting subsystems that behave in nonlinear and unpredictable ways, one should at least be open to the possibility of uncertainty and unpredictability, and to the limits of knowledge. Indeed, this is the very point made by Judith Curry, a leading atmospheric scientist, who refers to the vast problem of forecasting highly nonlinear systems like the climate, referring to the "uncertainty monster" (Curry and Webster 2011). But constructivist thinking, and in particular the kind of constructivism associated with a particular species of progressivism, tends to deny uncertainty. While humans play a central role in the climate change narrative, that role is oddly static. If humans are embedded within the climate system, and human institutions and technological systems are a part of it, one might expect an appreciation for how human-centered creativity responds to climate change in ways that preclude, or at least place limits upon, our ability to predict the future. There is a kind of "God's Eye View" perspective in which climate change advocates claim a kind of omniscience. A more appropriate perspective would be to assume a "Local Eye View." Complex systems possess the characteristic that there is no particular vantage point from which one can know everything. No observer is omniscient. Local observers have knowledge within their particular epistemic neighborhoods, but no agent has access to the entire system (Borrill and Tesfatsion 2011: 239–40).

But there are other reasons for the poisoned debate. Classical liberals from Hayek (1945) to Berlin (1969) have issued cautionary warnings about what happens when the state, or some entity seeking the blessings of the state, assumes it has a monopoly on the truth. If "they" believe x and others believe y, and if only x can be correct, then y is of necessity wrong. If one also believes that ultimate truths governing the human condition are at stake, or in this case that the very survival of the human race is in the balance, then the failure to believe x is enough to consign nonbelievers to the outer darkness. If one denies climate change, or even the means of accomplishing certain goals, one is committing an act against humanity because one is wrong on an existential moral issue having to do with the survival of

the human race.[5] These are the dangers of the constructivist mindset when carried to its ultimate, logical conclusion. From the Robespierres of the French Revolution to the Stalins, Maos, and Pol Pots of the 20th century, moral certainty breeds intolerance and intolerance breeds extremists.

The Need for Popperian Epistemology

Skepticism about AGW theory continues to exist, and at high levels, because the massive computer models that have been constructed to predict global warming have consistently failed by overpredicting temperature increases, and by failing to predict the current 20-year "pause" (Shanahan 1992; also see Pindyck 2013 and Curry and Webster 2011). Of course, critics of the "pause" argument say that the data were flawed and that once corrections are made, the pause in temperature increases goes away. Needless to say, these arguments serve only to heighten suspicions among doubters, and to question the scientific integrity of the process. What may be required is full deployment of a Popperian epistemology to properly test the central propositions of AGW. Philosopher Karl Popper—an advocate of skeptical stances that encourage refutation—is perhaps unique among philosophers of science in rejecting the idea that we should seek to confirm our theories, as is typical among AGW proponents, but rather that we should seek to refute them. *Conjectures and Refutations*, one of Popper's key works, argues that the aim of science is to offer conjectures (hypotheses) that can be subjected to testing

[5]The recent dispute over the desirability of nuclear power provides a startling example of how activists are capable of turning on each other. When four leading scientists (James Hansen among them), all long associated with the AGW argument and the need for rapid decarbonization, suggested that fossil fuels must be replaced, at least in part, by nuclear energy, they were condemned by Naomi Oreskes, a professor of the history of science and a longstanding activist. Yet their position merely acknowledged the reality that renewable energy sources such as wind and solar will not, in anything like the foreseeable future, be able to fully substitute for fossil fuels. As such, the complete elimination of nuclear energy flies in the face of everything we know about the problem of switching from a fossil fuel–dominated system of energy production to carbon-free sources of production. Former Microsoft founder and CEO Bill Gates finds himself in this company as well. Gates, who has been arguing passionately for a major effort in technological innovation, recognizes that nuclear energy would play an important role in any future carbon-free energy infrastructure.

(Popper 1963). On the basis of these tests, new conjectures are proposed and new experiments conducted in an iterative process that allows investigators to get closer to the truth. Popper never believed that theories are final, even in phases (De Bruin 2006). They are always subject to refutation. Using a Popperian approach, Michaels (2015) and Michaels and Knappenberger (2015) provide a test of whether climate models are actually simulating reality. They conclude that the models suggest a degree of sensitivity of temperature changes to CO_2 that does not exist. As a result, the models overpredict temperature increases. These findings are reinforced by research from Kirby at al. (2016).

Popper's evolutionary epistemology captures, in our view, the essence of science, but the conduct of climate science today is a far cry from the scientific process that Popperian epistemology envisages. Popperian epistemology rejects inductivism, as evidenced by the famous "Black Swan" analogy. We may observe only white swans, but that does not mean there are only white swans. If we base scientific judgment on the assumption there are only white swans, all that is required to reject the theory is the observation of a single black swan. Such a black swan may be the current "pause" in global warming that has occurred even while the presumed cause of warming, CO_2, has continued to increase. To confirm this conjecture Popperian logic would require the formulation of testable hypotheses that either refute or confirm the original theory, with the results of the experimentation used to refine or replace the hypothesis, in an iterative process.

No such process is to be found in AGW climate science. Instead, there is a confirmation bias with an emphasis on statistical significance. With a paradigm asserted to be accepted science, research findings that contradict the status quo are ridiculed and the standing of the errant scientists is questioned. Ascendant AGW theory—married to left-liberal politics—has become the basis of national and global policy initiatives. People are told to be confident in the ability of policymakers not only to have a firm grounding in all the essential facts governing the climate today, but also to be able to understand and account for those processes decades in the future, taking into account an ever-evolving human-technological-climate interaction. The Black Swan pause, if it is a pause, may belie this belief: Type I errors may have been committed involving the assumption that there has been significant human-caused climatic

change that requires dramatic action, when in fact no such action is necessary. Type I errors are consistent with constructivist rationality that assumes that we can be highly confident in models used to predict climate change and to determine appropriate policy responses (see Heimann [1993] for an excellent discussion of the practical implications of Type I versus Type II errors). The alternative Popperian approach involves acquiring knowledge through posing a hypothesis, testing it, then reformulating your hypothesis in an iterative process (Popper 1963, De Bruin 2006).

Constructivists believe that global warming is occurring and that this warming is the product of human activity: if temperature data disagree with their models it is the data that are wrong and must be adjusted to conform. Smith (2003) and others advocating for an ecological approach to decisionmaking provide a much better framework for understanding the process of knowledge acquisition. This paper argues that, given the tentative nature of knowledge, Popperian epistemology offers an important counterpoint to constructivist approaches. We suggest that data-model differences are, in effect, Black Swans that require reformulation of one's hypothesis rather than, as seems so often the case, an effort to "massage" the data.

The Forcing Question

At the heart of the debate is the question of "forcing"—what causes what. If there is "warming," is it a consequence of increased levels of CO_2 produced by the burning of fossil fuels, or are changing CO_2 levels a consequence of the rise (and fall) of temperatures due to natural fluctuations in the climate system and varying solar inputs? The current climate science paradigm presupposes high temperature sensitivity to CO_2, and its modelers embed their assumptions about this sensitivity in large-scale climate models that predict runaway temperatures. True believers predict that the probability of catastrophic change is so great that there is little option but to act in dramatic fashion. Many environmental activists dream of a "de-developed" society in which fossil fuels and automobiles are banned and in which childbearing is strictly controlled to achieve Malthusian goals in a redefined humanity—Callenbach's green "Ecotopia" (1990). Even those who doubt that the effects of climate change will yield catastrophic results (Weitzman 2009), think that the consequences of ignoring a very low-probability, high-impact event that

actually occurs are unacceptably high. For them, use of the precautionary principle inevitably suggests moving toward a society so risk-averse that the very basis of scientific and technological advance is threatened.

There are, of course, a variety of possible responses if climate scientists' predictions turn out to be valid:

- Do nothing, because efforts to reduce greenhouse gas emissions are too little and too late.
- Take incremental action, applying a "wait and see" approach combined with efforts to reduce greenhouse gas emissions in a manner consistent with continued economic growth, a gradual phase-out of carbon-based fuels, and the deployment of new energy sources.
- Take dramatic action immediately in an effort to significantly reduce greenhouse gas emissions by 2050. Such an effort presumably would be designed to stabilize the global temperature increase by 2100 in the 2.5–3 C° range.
- Concentrate on adaptation rather than mitigation, for example by employing geoengineering technologies designed both to reduce the increase in temperatures and to keep CO_2 concentrations below the critical level of 450 ppm.
- Engage in some combination of mitigation and adaptation as defined above.

Beyond these are a multiplicity of somewhat radical proposals for technological fixes. They include the use of aerosols, sprayed into the stratosphere to create greater reflectivity, thereby deflecting solar radiation back into space; the placement of vast solar mirrors in space to deflect solar radiation; genetically engineering arboreal forms designed to absorb larger amounts of CO_2 than trees and plants do in their natural form; and algae or bacterial organisms that will have similar effects in reducing the amount of CO_2 in the oceans. Less dramatic are proposals to reduce CO_2 production via advanced electric battery technology, fed by improvement in solar energy capture, and the deployment of improved nuclear reactors—even the transition to nuclear fusion, although the problem with nuclear energy is one of political will and the opposition of the radical environmental groups who are the backbone of the AGW movement.

Of course, if skeptics (e.g., Loyola 2016) are correct, the complexity of climate change—in which humans play some role but are not

the sole agent—suggests that we should not have great faith in any of our existing models. As Michaels (2015) and Michaels and Knappenberger (2015) have shown, these models exaggerate the extent to which CO_2 forces increasing temperatures.

The Realities of Complex Systems

The problem is that each of the solutions proposed above ignores the complexity of the decision that would need to be made—one which demands comprehension of a complex adaptive system like the environment. Too often, that decision is reduced to a rhetorical question: Do you or do you not believe in climate change? If you do believe, your only realistic option is to radically reduce greenhouse gas emissions in the next few decades. Yet uncertainties exist at each step. The seeming unwillingness of the AGW community to articulate the existence of any uncertainties and to reduce any and all skeptics to a kind of caricature (the "deniers") does not seem consistent with the traditional conduct of science and notions of scientific objectivity. Pindyck (2013), certainly no global warming denier, has gone further, cautioning that using climate change models to determine policy is not a worthwhile enterprise. The models are simply not sufficiently precise to allow for effective policymaking. Moreover, it is necessary to consider the policy interdependence of potentially catastrophic events (Martin and Pindyck 2015). As noted earlier, Loyola (2016) points out the severe limitations of the current models, and considers the anthropogenic nature of climate change as being embedded within much larger cycles of variability that are produced by natural processes. There is also the critical need to address other aspects of the human condition (see Sen 2014), particularly in the developing world.

An example of the ever-evolving knowledge of the mechanisms involved in warming is provided by Kirkby et al. (2016), who find that highly oxidized organic compounds play a role in cloud formation. This finding has important implications: namely, that climate models may have underestimated the amount of cloud cover in preindustrial times. If that is the case, it means that the amount of radiative forcing from anthropogenic activities has been overestimated too. In turn, that points to global warming estimates over the next century toward the low end of the 1.5–5 C° prediction range. While certainly

not the last word, this research serves to highlight the very tentative nature of the climate change models.

Even if the AGW thesis is entirely correct, its true believers typically ignore the considerable benefits increased levels of CO_2 and global warming may bring. Greenpeace founder Patrick Moore has taken his successors to task in a powerful statement of the benefits of rising CO_2. He says:

> It is a proven fact that plants, including trees and all our food crops, are capable of growing much faster at higher levels of CO_2 than present in the atmosphere today. Even at today's concentration of 400 ppm plants are relatively starved for nutrition. The optimum level of CO_2 for plant growth is about 5 times higher, 2000 ppm, yet the alarmists warn it is already too high. They must be challenged every day by every person who knows the truth in this matter. CO_2 is the giver of life and we should celebrate CO_2 rather than denigrate it as is the fashion today [Moore 2015].

Moore, of course, is making the point that higher CO_2 levels create the conditions for plant growth, thus allowing for more food to be grown. Higher CO_2 levels should be a boon for those concerned with feeding global populations. He concludes with "a challenge to anyone to provide a compelling argument that counters my analysis of the historical record . . . much of society has been collectively misled into believing that global CO_2 and temperature are too high" (Moore 2015). It is worth emphasizing that Moore is someone who has been at the forefront of the environmental movement. Whether he is correct or not, his views should at least be evaluated rather than automatically dismissed.

A Science is Never "Settled"

The AGW hypothesis hangs on the question of whether human-caused increases in global CO_2 are producing rising temperatures that are inimical to human welfare. While the great majority of the scientific community claims that the "science is settled," Siegel (2015), taking a Popperian stance, has reviewed the evidence and concluded the opposite. Critical thinking, he says, led to his skepticism and a series of realizations: policy always involves politics; political beliefs cloud the ability to process information; forecasts

are neutral constructs—tools, not truth; and consensus is not an argument for any scientific principle. There are, he says, key questions: What are the natural drivers of temperature and its variability? What do projected increases in temperature and greenhouse gases hold for the environment and people? Is decarbonization the solution? He concludes that Mann's hockey stick is wrong, produced by cherry picking data from tree rings and not supported by any other evidence; that government agencies have rigged data to support the AGW hypothesis; that solar forcing evidence provides better explanations for temperature change; and that rigged inputs and false assumptions about feedback have guaranteed the now well-documented climate model failures. Yet despite this, support for the hypothesis remains strong and aggressive because "Think tanks, NGOs, universities, the alternative power industry, consultants, government agencies, magazines, and others switched from scientific inquiry to rent seeking" (Siegel 2015: 41). Now, perhaps Moore and Siegel are wrong. Nevertheless, it seems foolish to simply dismiss their arguments, although this is precisely what the Kuhnian paradigm of "normal science" would expect. Is it asking too much for all parties to argue in a manner more consistent with a Popperian epistemological approach, seeking through conjecture and refutation to arrive at something closer to truth?

Mann's hockey stick model remains at the core of the AGW community's beliefs, even though it has been condemned as being unreproducible, a product of faulty methodology and likely scientific misconduct (Steyn 2015). Monckton (2015) looked to the current "pause" as evidence that Mann is wrong, finding that:

- Satellite data show no global warming at all for 224 months from February 1997 to September 2015—more than half the 441-month satellite record.
- There has been no warming even though one-third of all anthropogenic forcings since 1750 have occurred since the Pause began in February 1997.
- The entire satellite dataset from January 1979 to date shows global warming at an unalarming rate equivalent to just 1.2 C° per century.
- Since 1950, when a human influence on global temperature first became theoretically possible, the global warming trend has been equivalent to below 1.2 C° per century.

- The global warming trend since 1900 is equivalent to 0.75 C° per century. This is well within the range of natural variability.
- The warming trend since 1990, when the IPCC wrote its first report, is equivalent to 1 C° per century. The IPCC had predicted close to three times as much.
- The IPCC's prediction of 4.8 C° by 2100 is four times the observed real-world warming trend, since we might in theory have begun influencing temperatures in 1950.

While many will balk at the veracity of findings by nonscientists like Steyn and Monckton, and therefore reject their conclusions out of hand, these arguments are closely paralleled by Curry. That atmospheric scientist's "lukewarm" position basically asserts that global warming is real, that it is very likely anthropogenic (at least in some very substantial percentage), but that the threat from global warming on a time scale that could be of any relevance to us, say a century or longer, is unlikely to be substantial. If this is the case, then expending vast resources now on a problem that future technological advances may readily be able to address seems extremely short-sighted and may, indeed, prove counterproductive (Curry and Webster 2011; Curry, Webster, and Holland 2006).

Curry's position is similar to Ridley's (2015b). Ridley's thesis in *The Evolution of Everything* is that the top-down perspective of most climate modelers overemphasizes the role of CO_2 in climate change at the expense of other influences.

Ridley (2015b: 272) states:

> This explains, these sceptics (such as Judith Curry of the Georgia Institute of Technology) think, the failure of the climate to warm nearly as fast over recent decades as predicted. It also explains the fact that Antarctic ice cores reveal a clear relationship between temperature and CO_2 as the earth goes into and out of ice ages that is the reverse of that predicted by the theory: CO_2 levels follow temperature up and down, rather than precede them. Effects cannot precede causes, and we now know almost for sure that ice ages are caused by changes in the earth's orbit, with CO_2 playing a minor, reinforcing role, if any at all. In short, there is a tendency to overprioritize CO_2 as a cause of global temperature, rather than just another influence among many.

A Precautionary Stance?

As Deutsch (2011) points out, it is still not known just what degree of sensitivity the atmosphere has to any given concentration of CO_2. That relationship is critical, since its value determines how serious the climate change problem is. If the value is high—that is, the atmosphere is very sensitive—then the urgency is high. If it is extremely high there is little to be done. But this leads invariably to the question of the anthropogenic origins of climate change. Deutsch says that all sides seem to assume that if it turns out that a random fluctuation in the temperature is going to have disastrous consequences the best thing to do is just grin and bear it; or, if two-thirds of the increase is anthropogenic and one third natural, we are not supposed to do anything about the natural part. Most important, the point that trying to predict what our net effect on the environment will be for the next century and then subordinating all policy decisions to optimizing that prediction cannot work. As Deutsch (2011: 440) argues,

> We cannot know how much to reduce emissions by, nor how much effect they will have, because we cannot know the future discoveries that will make some of our present efforts seem wise, some counter-productive and some irrelevant, nor how much our efforts are going to be assisted or impeded by sheer luck. Tactics to delay the onset of foreseeable problems may help. But they cannot replace, and must be subordinate to, increasing our ability to intervene after events turn out as we did not foresee. If that does not happen in regard to carbon-dioxide induced warming it will happen with something else.

He goes on to note:

> There is a saying that an ounce of prevention equals a pound of cure. But that is only when one knows what to prevent. No precautions can avoid problems we do not yet foresee. To prepare for those, there is nothing we can do but increase our ability to put things right if they go wrong.

Picking up on Deutsch's "ounce of prevention" theme, Martin and Pindyck (2015) also reject the precautionary principle. Although they accept the reality of climate change, Martin and Pindyck also believe that, first, climate change models are not useful for making policy

due to the complex uncertainties contained in such models. Second, they believe that even if climate change represents a serious threat, one cannot consider it in isolation. Civilization, in their view, faces many potential threats of varying likelihood—whether global pandemics, nuclear war, or economic collapse. As a result, efforts to address one problem may limit our ability to address another. Depending upon the expected scale of the problem and the likelihood of such a problem actually arising, decisionmakers at a particular time may rationally decide not to commit resources to a specific problem.

The precautionary principle might, at first, seem quite reasonable. But where does one draw the line in terms of when the precautionary principle should be triggered: at the likelihood of catastrophe being 1 in 10? 1 in a 100? 1 in a 1000? As Ridley (2015b: 73) suggests:

> Blaise Pascal argued that even if God is very unlikely to exist, you had better go to church just in case, because if he does exist the gain will be infinite, and if he does not the pain will have been finite. To me this is a dangerous doctrine, which justifies inflicting real pain in the here and now on disadvantaged people on the basis of forestalling a distant possibility of doom. This was exactly the argument used by eugenicists: the noble end justifies the cruel means.

Carried to its logical conclusion, the precautionary principle could be used to completely paralyze our civilization and stymie progress for future generations—depriving our descendants of the chance to live in a much wealthier society than our own.

Conclusion

As awareness of the uncertainties of global warming has trickled out, polling data suggests that the issue has fallen down the American public's list of concerns. This has led some commentators to predict "the end of doom,' as Bailey (2015) puts it. In light of this, it seems odd to keep hearing that "the science is settled" and that there is little, if anything, more to be decided. The global warming community still asks us to believe that all of the complex causal mechanisms that drive climate change are fully known, or at least are known well enough that we, as a society, should be willing to commit ourselves to a particular, definitive and irreversible, course of action.

The problem is that we are confronted by ideologically polarized positions that prevent an honest debate in which each side acknowledges the good faith positions of the other. Too many researchers committed to the dominant climate science position are acting precisely in the manner that Kuhnian "normal science" dictates. The argument that humanity is rushing headlong toward a despoiled, resource-depleted world dominates the popular media and the scientific establishment, and reflects a commitment to the idea that climate change represents an existential or near-existential threat. But as Ellis (2013) says, "These claims demonstrate a profound misunderstanding of the ecology of human systems. The conditions that sustain humanity are not natural and never have been. Since prehistory, human populations have used technologies and engineered ecosystems to sustain populations well beyond the capabilities of unaltered natural ecosystems."[6]

The fundamental mistake that alarmists make is to assume that the natural ecosystem is at some level a closed system, and that there are therefore only fixed, finite resources to be exploited. Yet the last several millennia, and especially the last two hundred years, have been shaped by our ability—through an increased understanding of the world around us—to exploit at deeper and deeper levels the natural environment. Earth is a closed system only in a very narrow, physical sense; it is humanity's ability to exploit that ecology to an almost infinite extent that is important and relevant. In other words, the critical variables of creativity and innovation are absent from alarmists' consideration.

In that sense, there is a fundamental philosophical pessimism at work here—perhaps an expression of the much broader division between cultural pessimists and optimists in society as a whole. Both Deutsch (2011) and Ridley (2015b) view much of the history of civilization as being the struggle between those who view change through the optimistic lens of the ability of humanity to advance, to solve the problem that confronts it and to create a better world, and those who believe that we are at the mercy of forces beyond our control and that efforts to shape our destiny through science and technology are doomed to failure. Much of human history was under the control of the pessimists; it has only been in the last three hundred years that

[6]Even the Food and Agricultural Organization of the United Nations, itself an organization deeply prone to accepting the latest scientific orthodoxies, has acknowledged that the nine billion people expected to inhabit the earth by 2050 can be sustained indefinitely provided that necessary investments are made.

civilization has had an opportunity to reap the benefits of a rationally optimistic world view (see Ridley 2010).

Yet the current "debate" over climate change—which is really, in Ridley's (2015a) terms, a "war" absent any real debate—has potentially done grave harm to this scientific enterprise. As Ridley documents, one researcher after another who has in any way challenged the climate orthodoxy has met with withering criticism of the sort that can end careers. We must now somehow return to actual scientific debate, rooted in Popperian epistemology, and in so doing try to reestablish a reasonably nonpolitical ideal for scientific investigation and discovery. Otherwise, the poisoned debate over climate change runs the risk of contaminating the entire scientific endeavor.

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