

Research to date on Forecasting for the Manmade Global Warming Alarm

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Abstract

The validity of the manmade global warming alarm requires the support of scientific forecasts of (1) a substantive long-term rise in global mean temperatures in the absence of regulations, (2) serious net harmful effects due to global warming, and (3) cost-effective regulations that would produce net beneficial effects versus alternatives such as doing nothing.

Without scientific forecasts for all three aspects of the alarm, there is no scientific basis to enact regulations. In effect, it is a three-legged stool. Despite repeated appeals to global warming alarmists, we have been unable to find scientific forecasts for any of the three legs.

We drew upon scientific (evidence-based) forecasting principles to audit the forecasting procedures used to forecast global mean temperatures by the Intergovernmental Panel on Climate Change (IPCC) –leg “1” of the stool. This audit found that the procedures violated 81% of the 89 relevant forecasting principles

We also did an audit of the forecasting procedures used for two papers that were designed to support proposed regulation related to protecting polar bears – leg “3” of the stool. On average, these procedures violated 85% of the 90 relevant principles.

The warming alarmists have not demonstrated the predictive validity of their procedures. Instead, their argument for predictive validity is based on their claim that nearly all scientists agree with the forecasts. Such an appeal to “voting” is contrary to the scientific method. It is also incorrect.

We conducted a validation test of the IPCC forecasts based on the assumption that there would be no interventions. This test found that the errors for IPCC model long-term forecasts (91 to 100 years in the future) were 12.6 times larger than those from an evidence-based “no change” model.

Based on our analyses, we concluded that the global warming alarm is an anti-scientific political movement.

We then turned to the “structured analogies” method to forecast the likely outcomes of this movement. In this ongoing study, we have, to date, identified 26 historical alarmist movements. None of the forecasts for the analogous alarms proved correct. In the 25 alarms that called for government intervention, the government imposed regulations in 23. None of the 23 interventions was effective and harm was caused by 20 of them.

Introduction

The Earth's climate clearly varies as can be seen from plots of temperature proxy data over hundreds, thousands, and hundreds-of-thousands of years, so the existence of climate change is not a matter of dispute. Global warming alarmist analysis is concentrated on the years from 1850, a period of widespread direct temperature measurement, increasing industrialization, and increasing concentrations of carbon dioxide in the atmosphere. As with other periods, during this period one can retrospectively identify upward trends and downward trends, depending on the starting and ending dates one chooses. Over the whole period that we examined, 1850 through 2007, global annual temperature proxy series constructed for the Intergovernmental Panel on Climate Change (IPCC) show a small upward trend of about 0.004°C per year. There is some dispute over the veracity of the proxy temperature series (Christy, *et al.* 2010). For our analyses, however, we treat the data as if they were correct. In particular, we use the U.K. Hadley Centre's "best estimate" series, HadCRUt3¹ as described in Brohan *et al.* (2006).

We approach the issue of alarm over dangerous manmade global warming as a problem of forecasting temperatures over the long term. The global warming alarm is not based on what *has* happened, but on what *will* happen. In other words, it is a forecasting problem. And it is a very complex problem.

To address this forecasting problem we first describe the basis of the scientific principles behind forecasting. We then examine the processes that have been used to forecast that dangerous manmade global warming will occur and the validation procedures used to demonstrate predictive validity. We then summarize a validation study that we conducted.

We limit our discussion to forecasting. Those who are interested in the relevant aspects of climate science can find summaries in Robinson, Robinson and Soon (2007) and in Idso and Singer (2009).

Based on our analyses, especially with respect to the violations of the principles regarding objectivity and full disclosure, we conclude that the manmade global warming alarm is an anti-scientific political movement. In an ongoing study, we identified analogous situations and report on their forecasts and outcomes.

The basis of scientific forecasting

Research on proper forecasting methods has been conducted for roughly a century. Progress increased over the past four decades due to an emphasis among researchers on experiments that were designed to test the effectiveness of alternative methods under varied conditions. Forecasting research has led to many surprising conclusions.

To make this knowledge useful to forecasters in all domains, I, along with an international and inter-disciplinary group of 39 co-authors and 123 reviewers, expert in various aspects of forecasting, summarized the evidence as a set of principles. A principle is a conditional action, such as "forecast conservatively in situations of uncertainty". There are now 140 forecasting principles. The principles are described and the evidence for them is fully disclosed in the *Principles of Forecasting* handbook (Armstrong 2001). The principles are also provided on the forecastingprinciples.com site (ForPrin.com), on which we invite researchers to contribute evidence either for or against the principles.

In practice, nearly everyone believes that their situation is different and that the principles do not apply. I suggest to such people that they conduct experiments for their own situation and publish their findings, especially if they contradict the principles, and by doing so advance the science of forecasting. There can never be enough situation-specific evidence for some people but, given the evidence that many common forecasting practices are invalid, it would be unwise to reject the principles without strong evidence for doing so.

¹ Obtained from <http://hadobs.metoffice.com/hadcrut3/diagnostics/global/nh+sh/annual>; notes on series at <http://www.metoffice.gov.uk/hadobs/hadcrut3/>

Conditions that apply in forecasting climate change

The global warming alarm is based on a chain of three linked elements, each depending on the preceding element and each element highly complex due to the number of variables and the types of relationships. It is much like a three-legged stool. Each leg involves much uncertainty (Idso and Singer 2009). The alarm requires:

1. a substantive long-term rise in global mean temperatures in the absence of regulations,
2. serious net harmful effects due to global warming, and
3. cost-effective regulations that would produce net beneficial effects versus alternatives such as doing nothing.

Effective policy-making requires scientific forecasts for all three elements. Without proper forecasts, there can be no sound basis for making policy decisions. Surprisingly, then, despite repeated appeals to global warming alarmists, we have been unable to find scientific forecasts for any of the three elements.

Of course, there have been many forecasts based on what we refer to as unaided expert judgment: judgments made without the use of evidence-based forecasting principles. For example, in 1896 the Swedish Nobel Prize winner in chemistry, Svante Arrhenius, speculated about the effect of increases in atmospheric carbon dioxide (CO₂) and concluded that higher concentrations would cause warming. His conclusion was drawn from an extrapolation of observational data². Arrhenius's idea attracted little attention at the time, perhaps because he expected benefits from warming, rather than an impending disaster.

As noted, the forecasting principles provide advice about how to forecast given the conditions. Here the evidence yields a finding that is surprising to many researchers: use simple methods when forecasting in a complex uncertain situation. This was a central theme in my 1978 book on long-range forecasting. Those involved in the global warming alarm have violated the "simple methods" principle.

Audit of methods used to forecast dangerous manmade global warming

Kesten Green surveyed climate experts (many of whom were IPCC authors and editors) to find the most credible source for forecasts on climate change. Most respondents referred to the IPCC report and some specifically to Chapter 8, the key IPCC chapter on forecasting (Randall *et al.* 2007).

Kesten Green and I examined the references to determine whether the authors of Chapter 8 were familiar with the evidence-based literature on forecasting. We found that none of their 788 references related to that body of literature. We could find no references that validated their choice of forecasting procedures. In other words, the IPCC report contained no evidence that the forecasting procedures they used were based on evidence of their predictive validity.

We then conducted an audit of the forecasting procedures using Forecasting Audit Software, which is freely available on forprin.com. Kesten Green and I independently coded the IPCC procedures against the 140 forecasting principles, and then we discussed differences in order to reach agreement. We also invited comments and suggestions from the authors of the IPCC report that we were able to contact in the hope of filling in missing information. None of them replied with suggestions and one threatened to lodge a complaint if he received any further correspondence. We described the coding procedures we used for our audit in Green and Armstrong (2007).

We concluded from our audit that invalid procedures were used for forecasting global mean temperatures. Our findings, described in Green and Armstrong (2007), are summarized in Exhibit 1. Based on the available information, 81% of the 89 relevant principles were violated. There were an additional 38 relevant principles, but the IPCC chapter provided insufficient information for coding and the IPCC authors did not supply the information that we requested.

² See description on Wikipedia and original paper at globalwarmingart.com/images/1/18/Arrhenius.pdf.

Exhibit 1: Audit of the IPCC forecasting procedures

<u>Principles were:</u>	<u>IPCC Chapter 8</u>
Violated	60
Apparently violated	12
Properly applied	17
<u>Insufficient information</u>	<u>38</u>
Total relevant principles	127

Much of the problem revolves around the use of computer modelers' scenarios as a forecasting method. As stated correctly by Trenberth (2007), a leading spokesperson for the IPCC researchers, the IPCC provides scenarios, not forecasts. Scenarios are not a valid forecasting method (Gregory & Duran 2001), but simply descriptions of their authors' speculations about what might happen in the future.

Warming forecasts and polar bears

We also examined two forecasts that were developed to support proposed policy changes. The reports assumed that there would be global warming as predicted by the IPCC. We examined the two reports that presented forecasts in line with the stated goal, mentioned on the first page of the report "to support US Fish and Wildlife Service Polar Bear Listing decision"—which we coded as a violation of objectivity. Our procedures were similar to those in our audit of the IPCC forecasts except that we also obtained coding by a climate scientist who has published papers on climate change in the Arctic. On average, these two reports violated 85% of the 90 relevant principles. For example, long-term forecasts were made using only five years of selected data. (Armstrong, Green & Soon 2008)

Exhibit 2: Audit of forecasting procedures used in two papers on polar bear populations

<u>Principles were:</u>	<u>Amstrup (2007)</u>	<u>Hunter (2007)</u>
Violated	41	61
Apparently violated	32	19
Properly applied	17	10
<u>Insufficient information</u>	<u>26</u>	<u>15</u>
Totals	116	105

One key violation was that they did not provide full disclosure of the data in their paper, and they refused our requests for the data. They also refused to answer our questions about key aspects of their procedures that were not fully described in their papers. They refused to provide peer review of our paper prior to publication. At our request, the editor of the journal invited them to provide commentary. They missed the deadline and our paper was published with commentary by other authors and with our replies to the commentary. We were surprised when their commentary appeared in the journal some months later without us having being offered an opportunity to respond. In their commentary, the polar bear scientists claimed "every major point in Armstrong *et al.* (2008) was wrong or misleading." You can read their commentary in Amstrup, et al. (2009) and form your own opinion.

Tests of predictive validity by global warming alarmists

For important problems, it is important to test the predictive validity of the forecasting methods used. Validation tests are normally done by simulating the conditions involved in making actual forecasts (called *ex ante* forecasts) by, for example, withholding some data and forecasting what that data will be. Thus, if one wanted to test the accuracy of a method for forecasting 50 years from now, one would make a series of 50-year-ahead forecasts using the method and one or more competitive alternative methods in order to compare the accuracy of the forecasts from the different methods.

We were unable to find any *ex ante* comparisons of forecasts by the alarmists.

In the spirit of doing a systematic evaluation of forecasts, in 2007 I invited former Vice President Gore to join with me in a test as to the whether forecasts by manmade global warming alarmists would be more accurate than forecasts from a no-change model. Each of us would contribute \$10,000 to go to the winner's favorite charity. The period of the bet was to be 10 years so that I would be around to see the outcome. Note that this is a short time period, such that the probability of my winning is only about 70%, based on our simulations. Had we used 100 years for the term of the bet, I would have been almost certain to win. Mr. Gore eventually refused to take the bet (the correspondence is provided on theclimatebet.com). So we proceeded to track the bet on the basis of "What if Mr. Gore had taken the bet" by using the IPCC 0.03°C per-year projection as his forecast and the global average temperature in 2007 as mine. The status of this bet is being reported on theclimatebet.com.

Claims of predictive validity by alarmists

The claim by alarmists that nearly all scientists agree with the dangerous manmade global warming forecasts is not a scientific way to validate forecasts. In addition, the alarmists are either misrepresenting the facts or they are unaware of the literature. International surveys of climate scientists from 27 countries, obtained by Bray and von Storch in 1996 and 2003, summarized by Bast and Taylor (2007), found that many scientists were skeptical about the predictive validity of climate models. Of more than 1,060 respondents, 35% agreed with the statement "Climate models can accurately predict future climates," while 47% percent disagreed. More recently, nearly 32,000 scientists have disputed the claim of "scientific consensus" by signing the "Oregon Petition"³.

Perhaps in recognition that alarmist claims of predictive validity cannot sustain scrutiny, expressions of doubt about the alarm are often parried with an appeal to the so-called precautionary principle. The precautionary principle is an anti-scientific principle designed to silence people who have reached different conclusions. Alarmists, such as James Hansen of NASA, have even suggested publicly that people who reach different conclusions about global warming have committed crimes against the state (reported in Revkin 2008). Such attempts to suppress contrary evidence were ridiculed by George Orwell in his book *1984*: The Ministry of Truth building was inscribed with the motto "Ignorance is truth." For a closer examination of the precautionary principle from a forecasting perspective, see Green and Armstrong (2009).

Experts' opinions about what will happen have repeatedly been shown by research to be of no value in situations that are complex and uncertain. In 1980 I surveyed the evidence on the accuracy of experts' judgmental forecasts and found that experts were no better at forecasting about complex and uncertain situations than were novices (Armstrong 1980). Bemused at the resistance to this evidence, I proposed my Seer-sucker theory: "No matter how much evidence exists that seers do not exist, seers will find suckers." More recently, Tetlock (2005) presented the findings of 20 years of research over the course of which he obtained over 82,000 forecasts from 284 experts on "commenting or offering advice on political and economic trends," which represented complex and uncertain problems. Consistent with earlier research, he found that the experts' forecasts were no more accurate than novices' and naïve model forecasts.

Our validation test of IPCC forecasting model

We conducted a validation test of the IPCC forecast of 0.03°C per-year increase in global mean temperatures. We did this starting roughly with the date used for the start of the Industrial Revolution, 1850. As it happens, that was also the start of the collecting of temperature from weather stations around the world. We used the U.K. Met Office Hadley Centre's annual average thermometer data from 1850 through 2007. Note that the IPCC forecast had the benefit of using these data in preparing the forecasts. Thus, it had an advantage over the no-change model.

To simulate the forecasting situation, we needed unconditional (ex ante) forecasts. These were obtained through 100-year forecasts for the years from 1850 through 2007. The period was one of exponentially increasing atmospheric CO₂ concentrations, which is what the IPCC modelers assumed for their "business as usual" model forecasts of 0.03°C per-year increase in global mean temperatures. Relative forecasting errors are provided in Exhibit 3.

³ See petitionproject.org for details.

Exhibit 3

Ratio of errors in IPCC (2007) forecasts to errors in “no change” model forecast from 1850 through 2007

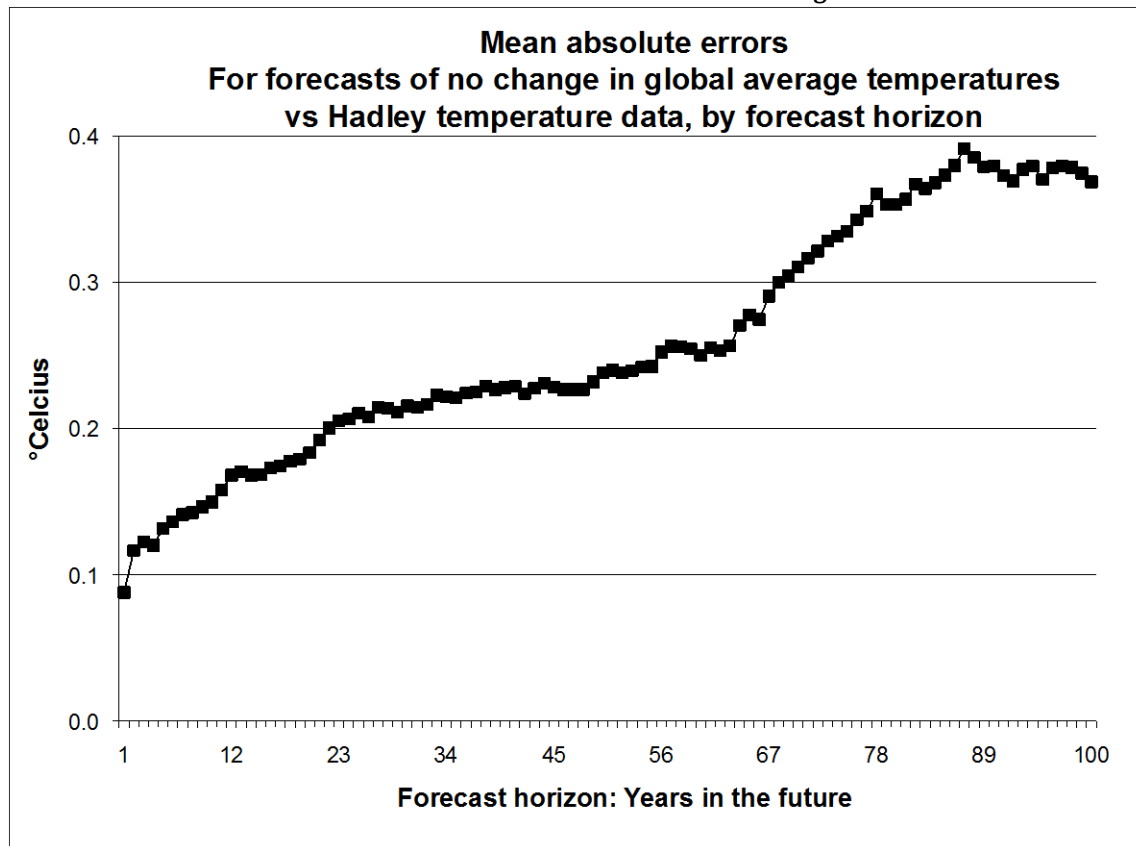
<u>Forecast horizon</u>	<u>Error Ratio</u>	<u># of Forecasts</u>
Rolling (1-100 years)	7.7	10,750
1-10 years	1.5	1,205
91-100 years	12.6	305

Note that the errors do not differ substantially in the short term (e.g., forecasting horizons from 1 through 10 years). As a consequence, the chances that I will win my 10-year bet with former Vice President Gore are not overwhelming. The IPCC model forecast errors for forecasts 91 to 100 years in the future, however, were 12.6 times larger than those for our evidence-based “no change” model forecasts. In an extension, we also examined a no-change model that used ten-year periods (instead of annual data) to forecast subsequent ten-year periods, updating this to make a forecast each year. The results were quite similar to those in exhibit 3.

Exhibit 3 shows relative errors, but it is also important for policy makers to look at absolute errors. Absolute errors for the no-change model are presented in Exhibit 4. The accuracy of forecasts from the no-change model are such that even perfectly accurate forecasts of global mean temperatures would not provide much help to policymakers. For example, the mean absolute errors for 50-year ahead no-change forecasts averaged only 0.24°C.

The alarmists claim that validation tests cannot be done because things have changed. Such claims are commonly, but illogically, made by people who believe that their situation is new or so different from other situations that they cannot learn from the past or from other domains.

Exhibit 4: Forecast errors for the no-change model



Conclusions from our analysis of the procedures used to forecast alarming manmade global warming

Global warming alarmists have used improper procedures and, most importantly, have violated the general scientific principles of objectivity and full disclosure. They also fail to correct errors or to cite relevant literature that reaches conclusion that are unfavorable. They also have been deleting information from Wikipedia that is unfavorable to the alarmists' viewpoint⁴ (e.g., my entry has been frequently revised by them). These departures from the scientific method are apparently intentional. Some alarmists claim that there is no need for them to follow scientific principles. For example, the late Stanford University biology professor Stephen Schneider said, "each of us has to decide what is the right balance between being effective and being honest." He also said "we have to offer up scary scenarios" (October 1989, *Discover Magazine* interview). Interestingly, Schneider had been a leader in the 1970s movement to get the government to take action to prevent global cooling. ClimateGate also documented many violations of objectivity and full disclosure committed by some of the climate experts that were in one way or another associated with the IPCC.

The alarmists' lack of interest in scientific forecasting procedures⁵ and the evidence from opinion polls (Pew Research Center 2008) have led us to conclude that global warming is a political movement in the U.S. and elsewhere (Klaus 2009). It is a product of advocacy, rather than of the scientific testing of multiple hypotheses.

Forecasts of outcomes of the manmade global warming alarmist movement

Using a process known as "structured analogies," we predicted the likely outcome of the global warming movement. Our validation test of structured analogies method was provided in (Green and Armstrong 2009).

Global warming alarmism has the characteristics of a political movement. In an ongoing study, we have been searching for situations that are "alarms over predictions of serious environmental harm that could only be averted at great cost." We have searched the literature, contacted various researchers -- especially those who believe in the global warming alarm. We have also posted appeals on email lists and on websites such as publicpolicyforecasting.com. We repeat this appeal here.

To date, we have identified 26 analogous alarmist situations in the past. Kesten Green and I independently coded the alarms. We coded them for:

1. Forecasting method.
2. Did the proposed action involve substantive government intervention?
3. Accuracy of forecasts was rated on a -1 to +1 scale
(-1 =wrong direction, 0=no, or minor, effect; +1=accurate)
4. Did substantive government intervention take place, or not?
5. Outcome of government policies to date on the value of their net benefit on a -1 to +1 scale
6. Persistence of government policies, to-date, on a 0 to 2 scale
(0=reversed; 1=no or little change; 2=strengthened)

⁴ <http://network.nationalpost.com/np/blogs/fullcomment/archive/2009/12/18/370719.aspx>

⁵ <http://blogs.telegraph.co.uk/news/jamesdelingpole/100017393/climategate-the-final-nail-in-the-coffin-of-anthropogenic-global-warming/> and <http://wattsupwiththat.com/2010/10/15/another-wikipedia-editor-has-been-climate-topic-banned/>

The descriptions include the following elements and references to sources of information:

1. Forecasts of impending catastrophe
2. Methods used to forecast the catastrophe
3. Actions called for (actions by government or by others)
4. Salient endorsements of the forecast by scientists and politicians
5. Challenges to the forecast
6. Outcomes of each conflict over the alarming forecast and calls for action, including forecast accuracy

We have posted full disclosure of our procedures at publicpolicyforecasting.com, and have sent announcements to websites and individual requests to people to comment. Thumbnail descriptions are available for nine of the 26 situations (indicated by italics in Exhibit 5) at publicpolicyforecasting.com.

Exhibit 5: Analogies to the alarm over dangerous manmade global warming
(Thumbnail descriptions available for italicized analogies)

	Analogy	Year
1	Population growth and famine (Malthus)	1798
2	Timber famine economic threat	1865
3	Uncontrolled reproduction and degeneration (Eugenics)	1883
4	<i>Lead in petrol and brain and organ damage</i>	1928
5	Soil erosion agricultural production threat	1934
6	<i>Asbestos and lung disease</i>	1939
7	Fluoride in drinking water health effects	1945
8	<i>DDT and cancer</i>	1962
9	Population growth and famine (Ehrlich)	1968
10	Global cooling; through to 1975	1970
11	Supersonic airliners, the ozone hole, and skin cancer, etc.	1970
12	Environmental tobacco smoke health effects	1971
13	<i>Population growth and famine (Meadows)</i>	1972
14	<i>Industrial production and acid rain</i>	1974
15	<i>Organophosphate pesticide poisoning</i>	1976
16	<i>Electrical wiring and cancer, etc.</i>	1979
17	CFCs, the ozone hole, and skin cancer, etc.	1985
18	Listeria in cheese	1985
19	Radon in homes and lung cancer	1985
20	Salmonella in eggs	1988
21	<i>Environmental toxins and breast cancer</i>	1990
22	Mad cow disease (BSE)	1996
23	Dioxin in Belgian poultry	1999
24	<i>Mercury in fish effect on nervous system development</i>	2004
25	Mercury in childhood inoculations and autism	2005
26	Cell phone towers and cancer, etc.	2008

Exhibit 6 provides an example:

Exhibit 6: Example of a thumbnail description of an analogy to the global warming alarm

Title: DDT and cancer

Date: Started in 1962

Forecast of impending disaster: Based on a book, Rachel Carson's *Silent Spring*, DDT was claimed to be a dangerous cancer-causing chemical. Publication of the book was followed by what some called a national hysteria. The alarm over forecasts of DDT's harmful effects combined concerns about the health and wellbeing of people with concerns about other species. Papers by scientists purported to demonstrate harmful effects on people from DDT exposure.

Forecasting method: A scenario based on the author's speculations from various pieces of information about the effects of DDT. There was no direct evidence that DDT harmed people.

Actions called for: Governments were asked to ban exports of DDT and World Bank loans would be banned to countries that used DDT.

Endorsements of and challenges to the forecast: Leading scientists from institutions (such as Stanford University), politicians (such as Senator Al Gore,) and a report by a commission appointed by President Carter. The reports of the dangers were widely covered by the mass media.

Outcomes of the conflict: The U.S. Environmental Protection Agency (EPA) banned the use of DDT following an 80-day hearing in 1972. Europe and Africa, under pressure from international agencies, did too. No actual harmful effects on humans have been found to result from DDT. Millions of people have died from mosquito-borne diseases such as malaria. The EPA decision was based on two studies of animals: the first could not be replicated and the second used a flawed experimental design.

Sources: Edwards (2004); Waite (1994)

Here are our preliminary findings. None of these alarming forecasts were correct. Twenty-five of them called for government intervention. In the 23 cases where interventions occurred, none were effective. The policy changes caused harm in 20 of the cases.

The findings will change as the project progresses and as we identify new analogies, provide more and better description of the analogies, and obtain codings from others, especially from experts in the various areas.

We were not surprised by the outcomes, as none of the alarms were based on scientific forecasts. They typically began with stories and progressed from there with appeals to scientific support. Another reason that we were not surprised is that our findings had been anticipated by others. For example, after compiling a list of analogous situations (source), Julian Simon said, in 1990, "As soon as one predicted disaster doesn't occur, the doomsayers skip to another... why don't [they] see that, in the aggregate, things are getting better? Why do they always think we're at a turning point—or at the end of the road?" And considerably earlier, in 1830, Thomas Babington Macaulay concluded, "On what principle is it that when we see nothing but improvement behind us, we are to expect nothing but deterioration before us?"

As with our other publications related to climate change, we have received no funding, so we expect this study to drag on. The good news is that it will allow an opportunity for researchers to provide peer review and to suggest further improvements in our study – or, better, to conduct independent studies of analogies.

Recommendations

Efforts to forecast climate change should include those who have expertise in evidence-based forecasting methods. After all, public policy changes are avowedly implemented in the expectation that they will make things better in the future than they would otherwise have been.

To help ensure objectivity, government funding should *not* be provided for climate-change forecasting. Kealey (1996) summarized evidence on the dangers of bias in government-funded research. The government should instead rely on independent forecasters.

As we have noted, simple methods are appropriate for forecasting for climate change. Large budgets are therefore not necessary. Private individuals have been willing to invest much time and effort in examining the global warming alarm without external rewards. In fact, a number of them have engaged in research on the global warming alarm at great personal cost. The cost has been at least in part because governments have almost universally sponsored scientists who have supported the manmade global warming alarm and these scientists have, as a consequence, attained considerable power over learned societies, journals, funding, and universities. With the power has come influence over the news media that, by their nature, are attracted to stories such as environmentalist alarms that grab the attention of audiences

The burden of proof should be on government to provide convincing scientific proof before increasing the burden of laws and regulations. It is not defensible to use anti-scientific procedures such as asking scientists or scientific organizations to “vote” on policy recommendations, even when the experts are provided with excellent information. This is especially so given the evidence that that expert opinions are useless for complex problems such as climate change.

Instead government should look for strict standards of objectivity in the evidence. Thus we suggest that government should address each of the legs on the three-legged stool involving climate change, effects of climate change, and outcomes of alternative proposed policy changes, including “don’t just do something, stand there!” The following should be included for each leg:

1. evidence, rather than experts’ opinions,
2. research from scientists with diverse views,
3. research that involves testing of multiple reasonable hypotheses,
4. use of scientific (evidence-based) forecasting methods
4. full disclosure of data and research methods,
5. criticism, replications, and extensions, and
6. testimony from scientists who have nothing to gain from the acceptance of their evidence.

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