Causes and Consequences of the Climate Science Boom

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The market economy is not the only arena of human interaction to experience booms and busts. Science is another. We argue that government policies and funding as well as the emergence of a scientific "Big Player" that has aggressively championed the hypothesis of anthropogenic global warming (AGW),[1] the United Nations Intergovernmental Panel on Climate Change (IPCC), have together fomented a boom in climate science that began in the early 1990s and has grown markedly over the past decade.

Recent science booms (and ensuing busts) in the United States include the boom in space science and some related disciplines in the aftermath of the Sputnik launch in 1957 and the boom in computer science prompted by the Japanese "Fifth Generation" project in 1984. These phenomena were relatively short-lived, and the busts came when political interest (and funding) waned because the purported crisis was no longer seen as a pressing concern. More comparable to the situation in climate science would be the long-lasting scientific booms in eugenics and nutrition science.[2]

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1. The AGW hypothesis holds that the overwhelming explanatory factor for the global warming observed during the past century, particularly since 1970, is that it is being forced by the emission of carbon dioxide and other greenhouse gases as a byproduct of human activity.

2. For a description of the space science episode, see Dow 1991; for the computer science episode, see McCorduck 2004, 426–29; for eugenics, see Crichton 2004, Selden 2005, and Bashford and Levine 2010; and for nutrition science, see Taubes 2007 as well as Butos and McQuade 2012.

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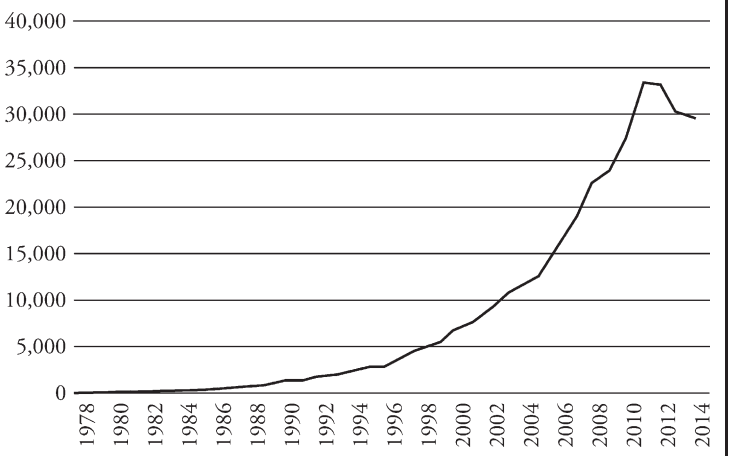
Figure 1
New Climate Science Papers, 1978–2014



Source: Data compiled from Google Scholar search using the key word *anthropogenic climate change*.

The eugenics boom, although very adequately funded, came to an end with the exposure of the eugenics-inspired atrocities committed by the Nazis, and the nutrition science boom has slowly (and quietly) given way to the gradual accumulation of empirical evidence difficult to fit within the government-favored hypothesis. In both of these cases, the object of scientific study was, like the climate (and the economy), a complex system that was not susceptible to the precision of empirical testing possible on simpler physical systems.

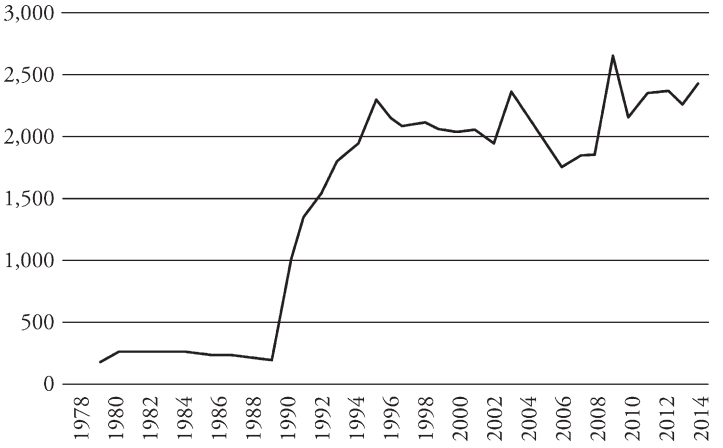
Evidence for an ongoing climate science boom can be seen in figure 1, showing the trend in published climate science papers,[3] and in figure 2, showing the trend in the level of U.S. federal government funding of climate science research and development (R&D), initially via the National Climate Program Office and later via the U.S. Global Change Research Program. Whether this boom is sustainable or not is another matter; we argue here that there are strong indications that it is artificial and unsustainable, but we offer no predictions of the nature or the timing of the bust.

Our exposition of the causes and consequences of the climate science boom proceeds as follows:

(*a*) We invoke the economic theory of the Big Player and indicate how this theory can be applied not only to market interactions but also to science. We identify

3. Similar searches at Google Scholar, employing keywords such as *climate global warming,* give results of similar magnitude and shape, so although the meanings of some significant words have changed over time (such as *change*, which once referred to "cooling" and now refers to "warming"), the general result is robust. Analogous exponential growth is seen in more focused surveys of peer-reviewed papers reported in Cook 2011 and Cook et al. 2013.

Figure 2
U.S. Federal Funding for Climate Science Research (in Millions of 2009 Dollars), 1979–2014



Note and Sources: The data shown here are funding disbursements by the White House U.S. Global Change Research Program and its predecessor, the National Climate Program, available at NCP 1988, 43; Climate Science Watch 2007; and Leggett, Lattanzio, and Bruner 2013. These data, however, do not represent congressional climate science funding appropriations to other government agencies. As we show later in a more detailed assessment of U.S. government climate science funding, the numbers here, especially those for more recent years, greatly underestimate the actual level of funding.

two Big Player types in the climate science saga, with separate but intertwined effects: the government funding agencies who dominate the financing of research and the IPCC, whose pronouncements about the state of the science carry enormous clout. We describe how the herding induced by the IPCC in the scientific arena interacts with the government-funding activities in mutually reinforcing ways.

(*b*) We provide data on the recent levels of funding for both basic climate science research and other government-sponsored activities that presume the accuracy of the IPCC climate projections. Our findings indicate that government-funded climate science and technology have massively increased over the past twenty years.

(*c*) The IPCC's operations are found to entail "crony science." We highlight the organization's political nature, its unscientific procedures for generating "consensus," and the editing of its summaries by political appointees, and we document the alleged violations of scientific procedure by some of the more ideologically committed scientists.

(*d*) In assessing the sustainability of the boom, we note the complex and unpredictable nature of the climate and the inconclusive nature of the evidence amassed so far in establishing a case for any of the hypotheses put forward to account for the warming trend observed over the past century.

(*e*) With policy preceding the science, a host of crony capitalist enterprises has emerged to seize on government support of the AGW hypothesis to obtain loans, tax breaks, and other financial backing from public sources, and we document the overall performance of these entities to date.

Our overall conclusion is that a confluence of scientific uncertainty, political opportunism, and ideological predisposition in an area of scientific study of phenomena of great practical interest has fomented an artificial boom in that scientific discipline. The boom is driven and sustained by the actions of Big Players—the IPCC and various government entities—in funding the boom and singularly in promoting only one among a number of plausible hypotheses describing the relevant phenomena. Given the scientific uncertainties inherent in the system under study[4] and the incentives for continued political involvement (even in the face of widespread failures in government-supported businesses whose activities were premised on the reliability of the AGW hypothesis), it is possible, even likely, that the boom will persist for a considerable time, as did the previous booms in eugenics and nutrition science. The likelihood of a continuation of generous funding to maintain the boom is bolstered, on the one hand, by a widespread faith (among both scientists and the general public) in government's ability to solve problems through legislation and control and, on the other, by the political attractiveness of a putative crisis apparently calling for a large expansion of state power (see White House 2013).[5]

Big Players in Markets and Science

Big Players, as described by Roger Koppl in an economic context, are "privileged actors who disrupt markets" in the sense that although they are not subject to market constraints or to the discipline of market competition, their discretionary actions have widespread impacts on market participants' expectations and actions (2002, 120–23; see also Butos and Koppl 1993; Koppl and Langlois 1994; Koppl and Yeager 1996). Their effects are felt in two ways: in the diversion of entrepreneurial concern away from the assessment of fundamental economic data and toward the attempted prediction of the activities of the Big Player and in the blunting of the weeding-out effects of the normal market mechanisms on participants less adept at appraising economic data, especially in the cases of those data actively favored by the Big Player.

4. For quick summaries of the uncertainties at issue, see Curry 2014 and Koonin 2014. There is the further complicating factor that in the midst of booms the participants usually are unaware of any problem with the boom activity, which serves as a self-reinforcing mechanism that perpetuates the boom. This characteristic blindness was in full display during the real estate boom, when investment seemed riskless and not participating was a sure way of being left behind, when talk of a "new economy" was rife, and when the majority of economists could see in their models only perfectly justifiable good times and ascribed warnings of unsustainability to the faulty analysis by a fringe.

5. Although we do not address here the "public-choice" considerations attendant to the motives for government involvement in science funding, see Butos and McQuade 2006 for a relevant discussion.

In markets, prototypical Big Players are central banks and government agencies empowered with discretionary policymaking. As Koppl argues, markets dominated by Big Players are prone to herding, where market participants, with little reliable information about the Big Players' next move, look to what others are thinking and doing (2002, 129–30; see also Butos and Koppl 1999).

That the Big Player phenomenon has relevance in science as well as in markets can be appreciated if it is understood that although markets and science, as systems of social interaction, differ vastly in the particular transactional forms employed, they are similar in their structural form.[6]

Scientists interact with each other in ways that are every bit as complex and structured as the interactions between market participants.[7] As scientists, they don't produce or buy and sell marketable goods, speculate on future asset prices, or seek financial gain and risk financial loss, but they do participate in interactions that have analogous feedback effects. They publish hypotheses and report experimental findings, use or criticize (and cite) the work of their peers, make choices about areas of research to pursue often based at least in part on anticipated reputational returns, and face the risk of loss of scientific credibility and funding. In both cases, market and science, the repeated interactions between the participants feed back recursively to generate emergent effects: in markets, a spectrum of goods, prices, and brand names that reflect the realities of resource availabilities, production technologies, and consumer tastes; in science, a body of knowledge and attendant scientific reputations that reflect the realities of the world under observation, experimental techniques, and the dictates of good practice.[8]

In markets, money is the essential component in all exchanges, and the manipulation of money by a discretionary central bank (a prototypical Big Player) can have unintended effects, including the promotion of unsustainable booms.[9] In science, the essential ingredient needed by most scientists to continue their participation is funding, and because science itself is not self-funding, this financial support must come from an outside source—an employer (often a university), a private donor, or a government entity. Sources of large amounts of funding directed to a specific area of scientific study can generate, in their (perhaps unintended) ability to affect the direction and content of

6. For a full exposition of this point, see McQuade 2007 as well as McQuade and Butos 2009.

7. See Hull 1988, 277–321, and McQuade and Butos 2003. And no discussion of the social structure of science, including this one, should fail to note its dependence on the path-breaking work of Robert K. Merton (1973, 1996).

8. On science as a self-regulating emergent order without a central locus of control, see the seminal work by Michael Polanyi (1962). Gordon Tullock, influenced by Polanyi, also sees science as a "functioning social mechanism which coordinates the activity of its members" and whose "organization . . . cannot be the result of conscious planning" (1966, 5–6).

9. The claim that monetary manipulations by central banks are a fundamental factor in the promotion of major economic booms is fully accepted within Austrian economic theory but less settled in the profession at large. For a full development of the Austrian business-cycle theory, see Garrison 2001. Also see Salerno 2012 for an application of this theory to the recent financial crisis.

research, an unsustainable boom of activity in that area. However, generous funding of a scientific discipline does not necessarily give rise to an unsustainable boom, and large increases in scientific activity in a particular area are not necessarily unsustainable.[10] So funding by itself, even if directed to favor one hypothesis over another, is not the problem; the problem arises when the provision of funding allows for or even encourages the continuation of research and publication activities that undermine the operation of the feedback inherent in the standard procedures of science—feedback that performs the scientific analog of profit and loss in assessing the scientific value of publications and in furthering their authors' scientific reputations.

In rare cases, science is also susceptible to another sort of Big Player, one with the ability to portray a favored hypothesis as settled, consensus scientific knowledge even in the absence of a substantial body of confirming evidence. This is difficult or impossible to carry off in the hard sciences. But when the object of study is a complex adaptive system, where the internal feedbacks are poorly understood and even incompletely identified and where the sharp and detailed prediction possible in the hard sciences is not feasible, the scope for extrascientific factors to enter into the assessment of hypotheses and therefore the scope for Big Player involvement are much higher. The role of scientific arbitrator can be pursued through application of force and intimidation, as the Soviet government did in the Lysenko episode in biology,[11] or more subtly by any organization that for political or ideological reasons has been able to set itself up as a respected voice qualified to assess the state of science in a particular discipline. The IPCC has taken on that Big Player role in climate science.

The IPCC and the Emergence of Consensus

Climate science has grown from a scientific backwater to an active, well-funded, and important area of research over a period of about thirty years.[12] In the 1980s, after a decade of generally rising global temperature measurements (which followed about thirty years of generally falling temperatures and some speculation about an impending ice age[13]), the hypothesis that the rise was driven by a greenhouse effect caused by carbon dioxide emitted as a result of human activity was debated, and

10. Molecular biology has been well funded in recent years, and the confirmed results have, if anything, exceeded expectations. Quantum mechanics saw extraordinary growth from the 1920s onward, which, far from being unsustainable, has changed the world and continues to do so.

11. The Lysenko affair lasted from the late 1920s to the early 1960s in the Soviet Union and other Eastern Bloc countries. Not only was it a serious setback for biological science in those countries, but its applications to agriculture also exacerbated the effects of the disincentives inherent in Communist management. See Soyfer 2001 and Graham 2002.

12. For a comprehensive history of developments in climate science, see Weart [2003] 2008.

13. Although there was no consensus (of any sort) in the scientific community regarding an imminent ice age prior to the 1980s, some peer-reviewed work did in fact raise the possibility of such a scenario—for example, Rasool and Schneider 1971. For some interesting documentation of the change in scientific opinion from likely cooling to likely warming, see Holcombe 2006.

although there was dissent, climate scientists widely saw the hypothesis as plausible.[14] But an extreme inference from the hypothesis—a human-induced global catastrophe—was publicized by environmental pressure groups, including the Environmental Defense Fund (Oppenheimer and Boyle 1990) and the Union of Concerned Scientists (1997), and so the tentative scientific hypothesis began to be transformed, without anything close to rigorous scientific confirmation, into almost-certain knowledge of an impending crisis of worldwide proportions in the face of which no reasonable person could remain unconcerned.[15] Funding in generous quantity, initially from philanthropic organizations such as the MacArthur Foundation (2008) but increasingly from various government agencies both in the United States and other countries overseas, began to be directed toward research projects in climate science, a significant part of which was explicitly aimed at documenting a real and present man-made danger.

The United Nations took up the issue in 1988, forming the IPCC as an independent body of scientists charged with assessing current climate science research (specifically emphasizing the effects of human activity on climate) and producing summary and detailed reports geared to public consumption—on the face of it, a very useful service.[16] But the way in which the IPCC is organized[17] and its methods for eliciting agreement on the conclusions given in its reports[18] have transformed it into the conduit of pervasive bias. Scientists are appointed to the panel by government officials; the panel's summary reports are edited by politicians and environmental activists without further scientific review; lax oversight allows scientists to assess their own work; relevant peer-reviewed literature is often ignored; and the much quoted percentage assessments of confidence in particular conclusions are arrived at by a process of discussion and compromise that is hardly a scientific method of characterizing uncertainty.

Nonetheless, the IPCC has emerged as the purveyor of definitive conclusions deduced from climate science research. And there are very good reasons why its

14. A seminal paper was Hansen et al. 1981, although this hypothesis was certainly not original with these authors. For a prominent example of dissent, see Idso 1980.

15. The rush to scientific judgment has been helped along by the active endorsement of the AGW hypothesis by some very prestigious scientific organizations, including the Royal Society in the United Kingdom (see Montford 2012) and the National Academy of Science in the United States (see Lindzen [2009] 2012, 7). The fact that scientific societies would take a strong public position on a matter of scientific controversy is unusual in itself and not in keeping with such societies' charters.

16. For an insightful exposition of the political and cultural currents surrounding the formation of the IPCC, see Gilland 2007.

17. The IPCC operates under protocols formalized at the Framework Convention on Climate Change of 1992; in Article 1.2, the term *climate change* is defined as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (United Nations 1994). This definition builds in a bias toward looking for the effects of human contributions to greenhouse-gas concentrations and downplaying natural causes.

18. For a general critique of the IPCC's "consensus-building" process, see Curry and Webster 2013.

pronouncements have been perceived as authoritative. If one does not inquire closely into the details of the process by which the panel produces its reports, it has the appearance of a thorough, competent, and disinterested body. It engages the unpaid services of hundreds of scientists and expert reviewers from all over the world in order to produce, every six years or so, an exhaustive summary of findings in many climate-related fields. Through a process of discussion and negotiation intended to resolve differences in interpretation, it purports to present, as one voice, a definitive assessment of the current state of the science. It enjoys the backing of governments around the world, and as a United Nations organization it has special status. Its receipt of the Nobel Peace Prize in 2007 cemented its reputation generally as a climate science oracle.[19]

The IPCC qualifies as a Big Player in science in that it possesses all of the attributes characteristic of Big Players in markets: bigness in terms of influence, insensitivity to the usual constraints, and discretion in its ability to promote a favored direction of research. Its influence in climate science is pervasive, and the complex nature of the climate system and the lack of understanding of the feedbacks at play enable the IPCC to champion the most politically attractive of the several plausible hypotheses and largely to ignore uncertainties and potential disconfirmations that are the usual scientific constraints on the acceptance of hypotheses. Professional success in climate science has become more tied to the acceptance of the IPCC's pronouncements than to the exploration of contrary possibilities; in fact, scientists who profess competing hypotheses are routinely castigated as "deniers," and some have reported unusual difficulties in negotiating the publishing process.[20]

Even though a large majority of climate scientists are reported as being in general agreement with the AGW hypothesis and with the IPCC's pronouncements, the accuracy and extent of this consensus have been questioned.[21] Yet, despite the objections to vaguely worded questionnaires, selectivity in sampling, subjectivity in the analysis of paper abstracts, and disputes as to who actually qualifies as a "climate scientist," the results of several surveys are consistent in depicting an overwhelming acceptance of the IPCC line by scientists associated in some way with climate

19. This cementing of the IPCC's scientific reputation occurred despite the fact that the Nobel Peace Prize is political and not scientific in nature.

20. It has been noted that many climate science papers whose findings do not provide obvious support for IPCC-endorsed conclusions and may indeed contradict them still include gratuitous endorsements of those conclusions. Richard Lindzen gives specific examples of papers that feature "the inclusion of an irrelevant comment supporting global warming [as] accepted wisdom" ([2009] 2012). This phenomenon may be indicative of the extrascientific pressures authors face in getting work published that does not endorse the AGW hypothesis.

21. For a comprehensive survey and assessment of peer-reviewed papers that document a strong AGW consensus, see Cook et al. 2013. Note, however, that some authors of papers assessed have contested the assessment criteria used in this survey (see, for example, *PopularTechnology.net* 2013). For a detailed critique of studies claiming to document consensus, see Guenier 2013. For a critique of "consensus polls," see Singer 2014.

science.[22] The oft-quoted 97 percent agreement among scientists may be unrealistic and unsupportable, but the general acceptance by the majority of scientists having any connection to climate science seems real enough. This herding is a predictable result of the IPCC's Big Player presence.

In science, when the "common wisdom" favors a particular hypothesis, there is an incentive, particularly for younger, not yet established researchers, to follow it. If the hypothesis turns out to be correct, you are seen to have the good sense to have espoused it; if it turns out to be incorrect, you have plenty of company. Either way, your scientific reputation will not be materially damaged. But if you flout the common wisdom, and it turns out to be correct, your reputation will suffer greatly. This raises the following question: Is the contrarian stance, with a potentially large reputational gain if the hypothesis turns out to be false, worth the risk? As Koppl points out, in the context of markets the value of the risk depends on the reliability of the evidence (2002, 129–30).[23]

Incentives influence the choice between idiosyncrasy and herding. If the penalty for a bad idiosyncratic decision is high compared with the penalty for the same bad decision made along with everyone else, then one has an incentive to concentrate less on evaluating reports about the empirical evidence and more on noting what other scientists believe. If the available reports about the empirical evidence are reliable, then they provide a powerful counterweight to this incentive—namely, the large gains to be expected from taking a correct but idiosyncratic position. When most of the available reports have been rendered unreliable by a Big Player's discretionary interventions, this counterweight no longer exists. The expected gain from taking a dissenting position then becomes too small to discourage herd behavior. Herd behavior is encouraged by discretionary interventions because of the role of reputation in the furtherance of scientific careers. The process is self-reinforcing—if herding begins, the fact that increasing numbers of scientists seem to espouse the common wisdom serves only to cement the appearance of consensus. The less reliable the available empirical assessments are, the longer such self-reinforcing movements can go unchecked.

The very nature of the IPCC's organization, from its politically motivated appointments of senior staff to its process of producing allegedly scientific summaries by negotiated compromise and its toleration of the intervention of political operatives in the production of the most publicized reports of the state of the science, has served to make it the purveyor of tainted science (see Curry 2013).[24] The introduction of political considerations has rendered the reported science unreliable and has obscured

22. See Doran and Zimmerman 2009; Anderegg et al. 2010; Cook 2010a; and Cook et al. 2013. But see also comment 12 in Cook 2010a by Spencer Weart, a respected physicist and historian of climate science, who says of the Anderegg paper, "[T]his paper should not have been published in the present form . . . the defects are obvious on a quick reading." For a comprehensive rebuttal of Cook et al. 2013, see Montford 2014.

23. In the following paragraph, we paraphrase Koppl directly, substituting science terminology for his market terminology.

24. Judith Curry's assessment of the IPCC's process is worth quoting: "Diagnosis: paradigm paralysis, caused by motivated reasoning, oversimplification, and consensus seeking; worsened and made permanent by a vicious positive feedback effect at the climate science-policy interface" (2013).

the uncertainties inherent in the studies of a very complex and poorly understood system. And as a herd-inducing Big Player in science, the IPCC has provided synergy for the interventions by Big Players of a different sort, the government entities that have seized on the IPCC-generated consensus to fund the climate science boom and thereby justify increasing economic interventions by citing the threat implied in the AGW hypothesis.

The Government's Role in Climate Science Funding

The past fifteen years have seen a sustained program of funding, largely from government or quasi-government entities.[25] The funding efforts are spread across a bewildering array of sources and buried in a labyrinth of programs, agency initiatives, interagency activities, and presidential offices, but what they seem to have in common is an adherence to the assumption that human activity is primarily responsible for the warming observed in the latter part of the twentieth century. Funding appears to be driving the science rather than the other way around, and the extent of this funding appears not to have been fully documented.[26]

Government-funded R&D, including those activities related to the development and financing of technologies and programs characterized as mitigation of and adaptation to the presumed effects of climate change, are embedded in scores of agencies and programs scattered throughout the executive branch of the U.S. government. Although such agency activities related to climate science have received funding for many years as components of their mission statements, the pursuit of an integrated national agenda to study climate change and implement policy initiatives took a critical step with passage of the Global Change Research Act of 1990. This act established institutional structures operating out of the White House to develop and oversee the implementation of the National Global Change Research Plan and created the U.S. Global Change Research Program (USGCRP) to coordinate executive departments' and agencies' climate-change research activities.[27]

The USGCRP operates as a confederacy of the research components of thirteen participating government agencies, each of which independently designates funds in

25. Here we concentrate exclusively on funding from U.S. government sources. Other governments, particularly in Europe, have also provided significant funding for climate science research.

26. Joanne Nova (2009) has made a good effort to assess the total funding, and here we extend her findings to probe deeper into the programs and agencies involved and their funding. Compared to our results, Nova's numbers are uniformly low, but we have had access to more recent and more detailed analyses of government spending, especially Leggett, Lattanzio, and Bruner 2013. In addition, Nova does not include climate-science-related funding that does not go through the Global Change Research Program, the climate technology programs, and tax subsidies—that is, additional monies that Congress authorizes to the various agencies that are seen in the American Association for the Advancement of Science (AAAS) reports referenced later in this article.

27. The USGCRP's motto is "Thirteen Agencies, One Vision: Empower the Nation with Global Change Science." For a full setting out of the Global Change Research Act, see USGCRP 2014.

accordance with the program's objectives; these monies make up the USGCRP's budget to fund agency cross-cutting climate science R&D.[28] The departments and agencies whose activities compose the bulk of such funding include independent agencies such as the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), the Environmental Protection Agency (EPA), the U.S. Agency for International Development, and the quasi-official Smithsonian Institute as well as executive departments such as Agriculture, Commerce (National Oceanic and Atmospheric Administration [NOAA], National Institute of Standards and Technology), Energy (DOE), Interior (DOI, the U.S. Geological Survey and conservation initiatives), State, and Treasury.[29]

As of 2014, the coordination of climate-change-related activities resides largely in the president's Office of Science and Technology Policy, which houses several separate offices, including Environment and Energy, Polar Sciences, Ocean Sciences, Clean Energy and Materials R&D, Climate Adaptation and Ecosystems, National Climate Assessment, and others. The Office of the President also maintains the National Science and Technology Council, which oversees the Committee on Environment, Natural Resources, and Sustainability and its Subcommittee on Climate Change Research. The subcommittee is charged with the responsibility of planning and coordinating with the interagency USGCRP. Also, the Office of Energy and Climate Change Policy is housed within the president's Domestic Policy Council. Although Congress authorizes executive-branch budgets, the priorities these departments and agencies follow are set by the White House. As expressed in various agency and executive-branch strategic plans, these efforts have been recently organized around four components: (1) climate-change research and education, (2) emissions reduction through "clean" energy technologies and investments, (3) adaptation to climate change, and (4) international climate-change leadership.[30]

Jane Leggett, Richard K. Lattanzio, and Emily Bruner (2013) of the Congressional Research Service provide a recent account of climate-change funding based on data from the White House Office of Management and Budget (see table 1). Total expenditures for federally funded climate-change programs from 2001 to 2013 were $110.9 billion in current dollars and $120.2 billion in 2012 dollars. "Total budgetary impact" includes various tax provisions and subsidies related to reducing greenhouse-gas emissions (which are treated as "tax expenditures") and shows total

28. It is important to note that the USGCRP coordinates *interagency* climate science programs. This factor carries the implication that USGCRP funding does not capture the entirety of the government's climate science R&D funding. This point is relevant later in our estimates of total government funding of climate science R&D.

29. International climate-change assistance is channeled through the Departments of State and Treasury and the U.S. Agency for International Development and totaled approximately $2.5 billion from 2012 to 2014.

30. See Leggett, Lattanzio, and Bruner 2013, 2–3. These four components were articulated in President Obama's Climate Action Plan (White House 2013). See Leggett 2013 and USGCRP 2012.

Table 1
Outlay for Federal Climate-Change Programs: Fiscal Years 2001–2013 Enacted and Fiscal Year 2014 President's Request

Major Climate-Change Program Areas	2001	2002	2003	2004	2005	2006	2007	2008	ARRA*	2009	2010	2011	2012	2013 est.	2014 Request	Total for 2001-2013
	In millions of nominal dollars, except where indicated otherwise															
USGCRP (including the former Climate Change Science Program)	1,728	1,667	2,078	1,996	1,864	1,691	1,825	1,864	641	2,023	2,195	2,448	2,506	2,463	2,658	26,989
Clean Energy Technologies (formerly Climate Change Technology Program)	1,675	1,637	2,533	2,870	2,808	2,789	3,485	6,394	25,499	5,216	5,504	5,646	6,121	5,783	7,933	77,960
International Climate Change Assistance	218	224	270	252	234	249	188	202	0	323	939	819	958	797	893	5,673
Adaptation	0	0	0	0	0	0	0	0	0	0	69	35	88	90	110	282
All Areas	**3,621**	**3,528**	**4,881**	**5,118**	**4,906**	**4,729**	**5,498**	**8,460**	**26,140**	**7,562**	**8,707**	**8,948**	**9,673**	**9,133**	**11,594**	**110,904**
All Areas in Constant 2012 $	**4,650**	**4,471**	**6,053**	**6,189**	**5,745**	**5,361**	**6,076**	**9,027**	**27,739**	**8,025**	**9,112**	**9,166**	**9,673**	**8,955**	**11,112**	**120,242**
Energy Tax Provisions	0	0	580	500	369	1,160	1,520	1,520	0	1,440	4,140	N.A.	10,132	13,079	9,839	34,440
Total Budgetary Impact	**3,621**	**3,528**	**5,461**	**5,618**	**5,275**	**5,889**	**7,018**	**9,980**	**26,140**	**9,002**	**12,847**	**8,948**	**19,805**	**22,212**	**21,433**	**145,344**
Total Bugetary Impact in Constant 2012 $	**4,650**	**4,471**	**6,773**	**6,793**	**6,178**	**6,676**	**7,756**	**10,648**	**27,739**	**9,553**	**13,444**	**9,166**	**19,805**	**21,779**	**20,542**	**155,431**

*ARRA = American Recovery and Reinvestment Act.

Source: Leggett, Lattanzio, and Bruner 2013.

climate-change expenditures from 2001 to 2013 to be $145.3 billion in current dollars and $155.4 billion in 2012 dollars.[31]

This summary and the details in table 1 do not capture, however, the full scale of federal funding for climate science R&D. Two complications must be considered to obtain a more accurate estimate. First, the entries in the first row of table 1 for climate science refer only to monies administered by the executive branch via the USGCRP office and do not include all climate-related R&D in the federal budget. For example, the entry for the USGCRP in 2011 is just less than $2.5 billion, yet the actual budget expenditures for climate-science-related R&D as calculated by the American Association for the Advancement of Science (AAAS) totaled about $16.1 billion (2012, 180). Second, because USGCRP funding comprises monies contributed from the authorized budgets of the thirteen participating departments and agencies, a more accurate estimate of climate-related R&D requires deducting USGCRP funding from the aggregated budgets of those thirteen. Both of these adjustments are included in table 2.

In addition, the entries for the departments and agencies in table 2 involve varying degrees of climate-related R&D. Table 2 does not provide a detailed programmatic allocation of these funds. A more careful breakdown reveals that the listed funding amounts are exaggerated because some entries are not proximate to climate-related R&D. The following examples illustrate this conclusion:

1. The DOE's Office of Science R&D lists about $4.6 billion in 2013, but most of this amount goes to physics R&D having little to do, at least directly, with climate.
2. Within DOE's Office of Science R&D, about only half of the subentry for Biological and Environmental R&D, $0.625 billion (not listed in table 2), is climate-relevant research.
3. Within the entry for NOAA, funding for the National Weather Service (not listed in table 2) averaged about $0.9 billion annually from 2010 to 2013. Yet this funding is not directly related to climate science.
4. The aggregate entry for the DOI in 2013 includes $87 million for a program entitled "New Energy Frontier: Renewable Energy," which concerns the environmental impacts of siting energy development on federal lands. Such monies are related only indirectly to climate research and perhaps warrant a separate category, such as climate-related "sustainability and adaptation."
5. Funds administered by the Treasury Department, as shown in table 2, are credit lines and loans channeled through the World Bank and earmarked for international organizations to finance clean technologies and sustainable practices; as a consequence, such funds would also more accurately be considered for climate-related sustainability and adaptation.

31. As seen in table 1, including the president's fiscal year 2014 Budget Request adds $11.6 billion in current dollars and $11.1 billion in 2012 dollars and increases the total budgetary impact in 2001–14 to $156.9 billion in current dollars and $166.5 billion in 2012 dollars. For detailed data on climate-change funding in the president's fiscal year 2014 Budget Request, see AAAS 2013, chap. 15.

Table 2
Climate-Related R&D in the U.S. Federal Budget: Fiscal Years 2010–2013

	2010 Actual	2011 Actual	2012 Estimate	2013 Budget
	In millions of current dollars			
USGRP Programs	2,187	2,448	2,427	2,563
NOAA (Climate Service, Oceanic & Atmospheric Research, Satellite Systems, and National Weather Service)	2,848	2,847	3,255	3,427
NASA (Earth Science Missions)	1,429	1,722	1,761	1,785
NSF (Geosciences, Atmospheric & Geospace Sciences, Earth Sciences, Polar Programs, and Education for Sustainability Programs)	1,414	1,414	1,478	1,559
DOE (Energy R&D, Office of Science R&D, and Biological & Environmental Research)	6,982	6,592	6,738	7,212
DOI (Landscape Conservation, Climate Variability Science, Adaptive Management, and Renewable Energy)	190	166	162	188
Treasury (Combatting Climate Change, Clean Technology Fund, Global Environmental Facility, Strategic Climate Funds, and Tropical Forest Conservation)	482	340	336	364
EPA (Clean Air, Climate, and Energy Programs)	534	576	509	546
Total	**16,066**	**16,105**	**16,666**	**17,644**

Sources: AAAS 2012, 2013.

Table 3 attempts to take into account these complications with the aim of estimating more accurately the magnitude and disposition of federal monies for climate science R&D and related activities. To be sure, the very opaqueness of these allocations and their actual use provides only for "ball park" estimates. However, we believe that the results presented in table 3 come closer to a useful accounting than what has previously been provided. We have combined data from Leggett, Lattanzio, and Bruner's work (2013) and data from the AAAS reports for fiscal years 2012 and 2013, the only years for which the AAAS has provided detailed budgetary data for climate science R&D and climate-related funding. The latter restriction constrains table 3 to data from 2010 through 2013 only. We have adjusted budgetary data and categorized it in light of discussion points 1–5 given earlier. Note that the estimated aggregate expenditures for climate science and climate-related funding (excluding tax subsidies) from 2010 to 2013 in table 3 are about twice that of the findings in Leggett, Lattanzio, and Bruner 2013.

By any of these measures, the scale of climate science R&D has increased substantially since 2001. Perhaps, though, the largest funding increases have occurred in developing new technologies and tax subsidies. As can be seen in table 1, federal dollars to develop and implement "clean-energy technologies" increased from $1.7 billion in 2001 to $5.8 billion in 2013, and energy tax subsidies increased from zero in 2001 and 2002 to $13 billion in 2013, with the largest increases happening since 2010.

The recent pattern of federal climate science funding, moving toward emphasis on the development of technologies and their subsidization through the tax system, suggests that climate-change funding has become more tightly connected to agencies such as the DOE, NASA, NOAA, and EPA as well as cross-cutting projects and programs that involve multiple agencies under integrating and coordinating agencies lodged within the executive branch, such as USGCRP. The allocations of budgets within these agencies are more directly determined and implemented by administration priorities and policies. We note that the NSF's traditional role in supporting basic science based on a system of merit awards provided (despite some clear imperfections) certain advantages with regard to generating impartial science. In contrast, even a casual perusal of current agency documents, such as *The National Global Change Research Plan 2012–2021* by the National Science and Technology Council, shows that those driving this movement make no pretense regarding their premises and starting points (see USGCRP 2012).[32]

32. Although it is no surprise that the plan is a masterpiece of "man of system" prose, its certainty as to the deleterious effects of human-induced climate change is quite notable. It begins with the statement that "[t]he rate of global change today . . . far exceeds anything observed and documented in human history" (USGCRP 2012, 1). It appears to be completely oblivious to the controversies that surround such a conclusion. The new phrase *global change,* if it means anything, is a more accommodating substitute for *global warming* and its postulated effects and is uniformly used in the sense of "change for the worse."

Table 3
Adjusted U.S. Federal Climate Science R&D and Climate-Related Expenditures, 2010–2013

Funding Categories	2010 Actual	2011 Actual	2012 Estimate	2013 Request	Total 2010–2013
	In millions of current dollars				
Climate Science R&D					
USGCRP[1]	2,195	2,448	2,506	2,463	9,612
NOAA[2]	2,848	2,487	3,255	3,427	12,017
NASA[2]	1,429	1,722	1,761	1,785	6,697
NSF (Geoscience, Polar Programs)[2]	1,344	1,326	1,315	1,356	5,341
DOE[2]	294	297	305	313	1,209
Total Climate Science R&D	8,110	8,280	9,142	9,344	34,876
Climate-Related R&D					
DOE: Energy R&D[2]	1,227	1,066	1,338	1,322	4,953
DOI: Climate Variability Science (USGS)	63	64	59	68	254
Total Climate-Related R&D	1,290	1,130	1,397	1,390	5,207
Climate Technologies					
Clean Energy Technologies[1] (formerly Climate Change Technology Program)	5,504	5,646	6,121	5,783	23,054
DOE: Energy R&D[2]	1,227	1,065	1,337	1,322	4,951
EPA[2]	235	263	223	233	954
Total Climate Technologies	6,966	6,974	7,681	7,338	28,959
Sustainability & Adaptation					
NSF (Education & Sustainability)[2]	70	88	157	203	518
DOI[2]	127	102	103	120	452
EPA[2]	299	313	286	313	1,211
Treasury (International loans)[2]	482	340	336	364	1,522
State & USAID (International Assistance)[1]	939	819	958	797	3,513
Total Sustainability & Adaptation	1,917	1,662	1,840	1,797	7,216
Total Program Spending	**18,283**	**18,046**	**20,060**	**19,869**	**76,258**
Compare amounts from table 1	8,707	8,948	9,673	9,133	36,461
Energy Tax Provisions[1]	4,140	N.A.	10,132	13,079	27,351
Total Budgetary Impact	**22,423**	**18,046**	**30,192**	**32,948**	**103,609**
Compare amounts from table 1	12,847	8,948	19,805	22,212	63,812

Notes:
(a) Entries for Climate Science R&D are adjusted as follows: we use data from table 2 but subtract from NOAA the budgets of the National Weather Service and from DOE the budgets of the Office of Science R&D while adding to DOE one-half of the budget for Biological and Environmental Research.
(b) The DOE also funds programs contained in table 2 under a subcategory called "Energy R&D"; we have apportioned half of these amounts under "Climate-Related R&D" and half under "Climate Technologies."
(c) The data for EPA in table 2 include two funding categories under "Science and Technology," which we include here under "Climate Technologies," and a third category "Environmental Programs and Management of Clean Air and Climate," which we include here in the category of "Sustainability and Adaptation."
Source: [1] Leggett, Lattanzio, and Bruner 2013.[2] AAAS 2012, 2013.

The impact of government funding on scientific research is a matter not only of the amounts but also of the concentration of research monies arising from a single source and brought to bear on particular kinds of scientific research. Government is that single source and has Big Player effects because it has access to a deep pool of taxpayer (and, indeed, borrowed and created) funds as well as regulatory and enforcement powers that necessarily place it on a different footing from other players and institutions. Notwithstanding the interplay of rival interests within the government and the separation of powers among the different branches, there is an important sense in which government's inherent need to act produces a particular set of decisions that fall within a relatively narrow corridor of ends to which it can concentrate substantial resources.

By any standard, what we have documented here is a massive funding drive, highlighting the patterns of climate science R&D as funded and directed only by the executive branch and the various agencies that fall within its purview.[33] To put its magnitude in context, the $9.3 billion funding requested for climate science R&D in 2013 is about one-third of the total amount appropriated for all twenty-seven National Institutes of Health (NIH) in the same year (see table 3 and NIH 2014), yet it is more than enough to sustain a science boom. Its directional characteristic, concentrated as it has been on R&D premised on the controversial issue of the actual sensitivity of climate to human-caused emissions, has gone hand in hand with the IPCC's expressions of increasing confidence in the AGW hypothesis and increasingly shrill claims of impending disaster.

Ideological Bias and the Undermining of Scientific Norms

Scientists are no less likely than anyone else to be swayed by a fear of crisis, and this is especially the case for those who believe that they may be able to use their relevant expertise to do something about the crisis. It is surprisingly easy for scientists to overstate the certainty of their results and to ignore or attempt to explain away conflicting data, but it is not unusual, and it does no lasting damage provided the basic procedures of science (review, publication, criticism, citation, and the feedbacks to reputation) are functioning normally. But when a particular set of conclusions is widely held not only to fit one's preconceptions but also to have serious social implications, the harsh and critical judgments necessary for weeding out shaky science can be significantly toned down. The transformation of the ideologically primed sense of impending global-warming catastrophe into near certainty by the IPCC's influential publications has endangered the integrity of the processes of science.

The scientific process for the generation of reliable knowledge relies heavily on general adherence to the norms of publication and citation, with feedback effects on the reputations and credibility of contributing scientists. Were these norms to be

33. It would be remiss not to mention the increasing opaqueness of climate science funding as the scope and magnitude of government funding as well as funding structures and programs increase.

systematically violated within a scientific discipline, knowledge and reputations would still be generated, but the knowledge would be counterfeit and unreliable, and the reputations would be similarly tainted.[34] In climate science, however, the presence of Big Players—the IPCC in its ability to direct the science and the government in its funding of IPCC-compatible science—has engendered a growing politicization of the discipline, which has shown up in the attempts to restrict publication of dissenting views and to attack the reputations of scientists who question the IPCC "consensus."

There have been a number of allegations of scientific misbehavior within climate science, ranging from extreme bias in the publishing process to stripping so-called deniers of their academic positions.[35] But these allegations are anecdotal, subject to claim and counterclaim, and cannot be held up as definitive evidence. Richard Lindzen, however, does attempt to document some serious instances of violations of scientific norms ([2009] 2012, sec. 4). These instances include pressure placed on some editors and reviewers to reject papers even mildly criticizing the AGW hypothesis, collaboration between some editors and reviewers with a view to suppressing papers critical of AGW, pressures on authors during the review process to remove findings that could be construed as disputing AGW, and instances of ostracization and vilification of some researchers for their publication of papers criticizing AGW. In addition, Lindzen claims that journals have solicited "attack papers" (published as independent papers rather than as critical comments, as is conventional) in the wake of publication elsewhere of papers considered to question AGW. If the original authors' rebuttals of the attack papers do get published, it is only after a long delay and as comments only so that the original papers appear to have been discredited.

These claims find some substantiation in the collection of emails and other data hacked from the Climate Research Center of the University of East Anglia in 2009.[36] In these messages, leading IPCC-affiliated scientists such as Michael Mann and his colleagues in the United States as well as Phil Jones and his colleagues in the United Kingdom[37] vent their distaste for researchers who dispute aspects of the AGW hypothesis, discuss their frustrations with requests for supporting data and their strategies for not complying with such requests, attempt to influence the reviewing process for papers they consider "dangerous," berate journal editors and reviewers for allowing dissenting papers to be published, and discuss boycotting journals thought

34. For a full discussion, see Butos and McQuade 2012.

35. See, for example, Douglass and Christy 2009; Readfearn 2012; Henderson 2014; and Morano 2014. Tullock (1966) offers a useful way of understanding the behavior of individual scientists who depart from scientific norms; his insights are revived and elaborated in Peart and Levy 2012. In particular, bias can arise from either quid pro quo (in funding, for example) or from ideological sympathy with a preferred result or from both. The sympathy motive can easily foster the formation of factions within the scientific discipline. We thank a referee for directing us to this material.

36. The hacked batch of emails and data, the so-called Climategate materials, are available in Wikileaks 2009.

37. The tight coauthoring relationships between these groups of climate scientists is documented in Wegman, Said, and Scott 2006.

to be open to such papers. In a message sent in 2004, Jones, then an IPCC chapter lead author, wrote in reference to two papers not supportive of AGW published in a peer-reviewed journal: "I can't see either of these papers being in the next IPCC report. Kevin and I will keep them out somehow—even if we have to redefine what the peer-review literature is!"[38]

Although this message reflects poorly on the IPCC's process of summarizing the extant peer-reviewed literature, and although the steadfast refusal to provide data to researchers attempting to reproduce published results is a clear violation of scientific norms, the extent of successful scientific distortion involved is hard to assess. It is not clear that the emails reveal more than a fairly extreme version of the egoism, competitiveness, sensitivity to criticism, and disdain for those not in agreement that is not uncommon in science circles. What does stand out rather clearly and consistently is the involved scientists' pervasive ideological bias. As might be expected, there is a great deal of discussion, expressed doubts, and disagreements among these scientists as to the reliability of their data, their assumptions, and the statistical methods being employed,[39] but none of this disagreement shows up in their public presentations.[40] It is not prominent in the IPCC reports to which these scientists are major contributors, either, and to the extent it appears at all it is buried in the jargon of the supporting scientific chapters but absent from the widely read summaries. There are excursions into political activism, with discussions about circulating alarmist statements for endorsement by other scientists (in furtherance of "the cause"), letters to the U.S. Senate, and encouragement of environmental agendas.[41] The line between science and politics in climate science does appear to be rather blurred.

Intimations of Scientific Unsustainability

We can group the intimations of the climate science boom's unsustainability into two categories: (1) emerging problems of scientific prediction and confirmation and (2) increasing disputation among knowledgeable researchers on the implications and relevance of particular data as well as growing questioning as to the methodological soundness of key investigations. Examined individually, these intimations could be dismissed as unfortunate but not unusual events in the

38. Email 1089318616 in the Climategate collection (Wikileaks 2009). "Kevin" refers to Kevin Trenberth of the U.S. National Center for Atmospheric Research, a fellow lead IPCC author.

39. See, for example, emails 0969618170, 0990119702, 1062592331, 1141398437, and 1255523796 (Wikileaks 2009).

40. In fact, there appears to be a great deal of concentration on maintaining a public appearance of settled science. See, for example, emails 0843161829, 0933255789, 1105019698, and 1225026120 (Wikileaks 2009).

41. See, for example, emails 0876437553 and 1058906971 (Wikileaks 2009). In email 0994083845, the writer expresses the opinion that even if the science that seems to support alarmism turns out to be wrong, "we should be trying to wean ourselves off of unsustainable energy generation and use anyway."

rough-and-tumble real world of scientific discovery, but taken together they indicate that all is not well in the discipline of climate science. Several examples can be given of empirical and methodological anomalies that are the subject of increasing controversy and whose very presence is indicative more of a scientific discipline in flux than of a settled science.

The IPCC reports detail what they call a "human fingerprint" in both greenhouse-gas concentrations and global temperature changes,[42] and, having estimated the parameters in various computer models on past observations of some, but not by any means all, known influences on climate, they run these models to project future trends. That there is a human contribution to the rising concentration of atmospheric carbon dioxide (CO_2) is not in dispute; neither is the basic mechanism of a greenhouse effect. Where there is uncertainty and dissent is in the estimates of climate sensitivity—the global temperature response to a doubling of atmospheric CO_2. The IPCC models produce a climate sensitivity "best estimate" of roughly 3°C (with a "likely" range of 1.5–4.5°C), whereas some instrumental observations suggest a much lower sensitivity.[43] In addition, the CO_2 response is modified by various (not all well-understood) feedbacks, both positive and negative, and whether the actual net effects of increasing CO_2 are discernable from the natural background variability or not is debated. Global temperature trends (both atmospheric and oceanic) in the past fifteen years (no significant warming and perhaps even a slight atmospheric cooling) have not adhered to the model predictions, which looked for an atmospheric warming of at least 0.3°C and oceanic warming of about 0.2°C over that period. Much effort is being expended to account for this "hiatus" in the upward temperature trend, and although some recent work suggests deep ocean heating, it is clear that there are significant natural processes not being accounted for in current climate models.[44]

Not only are the outputs of the models in question, but the inputs are too. There is controversy over the accuracy and the potential contamination of temperature measurements (especially land measurements taken outside the United States),

42. For a readable summary of evidence cited as pointing to a human contribution to global warming, see Cook 2010b. For rebuttals, see Nongovernmental International Panel on Climate Change (NIPCC) 2013.

43. The science here is still in flux, and a recent study by Steven Sherwood, Sandrine Bony, and Jean-Louis Dufresne suggests "[an equilibrium] climate sensitivity of more than 3 degrees for a doubling of carbon dioxide[,] . . . [which is] significantly higher than the currently accepted lower bound of 1.5 degrees" (2014, 37). However, work by Richard Lindzen and Yong-Sang Choi (2011) suggests a mean value of equilibrium climate sensitivity as low as 0.7°C; Roy Spencer and William Braswell (2014) suggest 1.3°C; and Nicholas Lewis and Judith Curry (2014) use data from the IPCC fifth assessment report to obtain an estimate of 1.64°C.

44. Hans von Storch and his colleagues note that "the continued warming stagnation over fifteen years, from 1998–2012, is no longer consistent with model projections even at the 2% confidence level" (2013). These authors posit three possible and not mutually exclusive reasons: "the underestimation of internal natural climate variability on decadal time scales . . . , the influence of unaccounted external forcing factors[, and] an overestimation of the model sensitivity to elevated greenhouse gas concentrations." Either of the latter two reasons would present a challenge to the AGW hypothesis. See Tollefson 2014 for an account of the most recent investigations.

and as a result even the very reliability of some temperature observations used in the IPCC's modeling efforts has been seriously questioned.[45]

In assessing the significance of such empirical problems, we need to keep in mind that the climate is a complex system that is subject to myriad influences, many of which are still incompletely understood, so that any modeling of the system as a whole must of necessity simplify potentially important factors and leave out others. It is not surprising that the predictive efficacy of such models should be limited; what is surprising is that the results of such modeling are taken as a firm basis for consensus among supposedly inherently skeptical scientists even though the science relevant for understanding many of the climate-forcing factors is still in its infancy. The extent, direction, and longevity of several potentially crucial temperature feedbacks are not currently known, and this lack of understanding of climate feedback amplification at the very least calls into question the climate models' predictive ability and makes the IPCC's "very likely" identification of man-made warming little more than a guess.

On the methodological front, a major source of continuing controversy has been the so-called hockey-stick graph, a product of the statistical analysis of data sets of both temperature proxy measurements and (where possible) instrumental temperature readings, the combination covering approximately the past one thousand years.[46] The study purported to show Northern Hemisphere temperature as reasonably constant except for a dramatic upturn in the past one hundred years (hence, the hockey stick image), so that the last decade of the 1900s appeared to be the hottest of the entire millennium. The results might have been looked at with some skepticism in view of the graph's virtual elimination of the well-documented medieval warm period[47] and the succeeding "little ice age," but the study was instead prominently featured in the IPCC's third report.[48] It has since been argued that the hockey-stick shape was an artifact of the manner in which some basic statistical procedures were employed.[49] Rebuttals and rebuttals of rebuttals have continued since, and the question of whether the temperatures of the late twentieth century are anomalous or not is still a matter of controversy.[50] But the very quick and prominent endorsement of what

45. See Pielke et al. 2007. Some of the controversy over temperature measurements centers on the "urban heat-island effect," in which measurements taken in or near urban centers tend to be biased on the high side (see NIPCC 2013, sec. 4.1.2).

46. See Mann, Bradley, and Hughes 1999, the conclusion of which (that late-twentieth-century temperatures were the warmest of the past millennium) has been disputed by Willie Soon and Sallie Baliunas (2003) in an article that itself became a focus of controversy for the refereeing procedures that led to its publication.

47. See, for example, Loehle and McCulloch 2008 and Wanner et al. 2008.

48. See figure 1, graph (b), in IPCC 2001, 3.

49. For a full discussion, see McIntyre and McKitrick 2005 and Wegman, Said, and Scott 2006. Edward Wegman published a paper based on this report, but it has been retracted due to plagiarism in a section of the paper (and the report) not concerned with the statistical findings.

50. However, work by Valérie Trouet and her colleagues (2009) not only confirms the reality of both the medieval warm period (with temperatures comparable to those of the current period) and the little ice age but also provides a mechanism for their occurrence in terms of large-scale atmospheric and oceanic circulation patterns.

has turned out to be a highly contestable result casts doubt on the efficacy of the IPCC's review and assessment procedures.[51]

A different type of methodological issue involves the "levels of confidence" and "likelihoods" that the IPCC reports have assigned to particular scientific hypotheses and to the reliability of model projections.[52] A confidence assessment "synthesizes the author teams' judgments about the validity of findings as determined through evaluation of evidence and agreement." As a qualitative assessment obtained by polling opinions, it does not (as the IPCC does make clear, at least to its authors) have any relationship to statistical confidence, although that distinction may be unclear to readers. A likelihood assessment, which "may be based on statistical or modeling analyses, elicitation of expert views, or other quantitative analyses," is associated with a numeric quantity (with "very likely," for example, being code for "90–100% probability"). Despite the authoratitive-sounding numbers, these likelihoods are no more a scientific assessment of probabilistic uncertainty than are the levels of confidence, as the inclusion of the phrase "elicitation of expert views" should make clear. This conflation of a level of scientific consensus with a negotiated compromise between the judgments of selected participants in a panel is highly misleading. Consensus of the IPCC's sort is certainly no substitute for the normal scientific process of criticism, testing, and use out of which real consensus is emergent.

The point of detailing these issues is not simply to illustrate that competing hypotheses are active in climate science[53] but to show that significant elements of what is being publicized as the "settled consensus" are in fact continuing to be disputed in scientific terms. Ever since the AGW hypothesis was put forward, individual scientists and statisticians have seriously questioned the circumstantial evidence presented, the methodologies employed in work supporting the hypothesis, and the reliance on tuned climate-model projections as major clinching arguments.[54] More recently, the level of scientific dissent has grown markedly, and organizations such as the Nongovernmental International Panel on Climate Change (NIPCC, which includes a broad cross-section of scientific expertise) and The Right Climate Stuff Group (TRCSG, a group of retired NASA engineers and scientists) have arisen to publicly dispute the IPCC's conclusions.[55] Rather than settling down, the scientific controversy is

51. See Holland 2007 and Von Storch and Zorita 2007. For a recent detailed assessment of the IPCC's review procedures, see Dixon 2013.

52. The definitions and instructions given here are in the IPCC instructions to authors for its fifth assessment report (IPCC 2010).

53. A full airing of the scientific controversy is given in NIPCC 2013, which challenges many of the assessments detailed in IPCC 2013.

54. See, for example, Lindzen 1999; Singer 1999; Jewson, Rowlands, and Allen 2009; Lewis 2013; and Montford 2013.

55. The most recent reports published by these groups are NIPCC 2013, 2014, and TRCS Research Team 2013. The NIPCC, responding to the phenomenon we have identified as "herding" due to Big Player effects, quite reasonably points out that a completely independent assessment of results and hypotheses emphasized by the IPCC would only enhance the reliability of any common conclusions. John Ioannidis (2005) makes the general point that independent studies of the same areas of research are desirable.

continuing unabated, with the stubborn lack of any direct empirical evidence for the IPCC's projections fueling increasing doubt and suggesting that the climate science boom could be in trouble.

Crony Science Begets Crony Capitalism

When a scientific discipline is subject to Big Player influences that circumvent normal scientific procedure to favor a particular hypothesis and to inject political considerations into the assessment of scientific achievement, the result can be termed "crony science," like the "crony capitalism" of an economy where particular industries and individual businesses are favored and the normal operation of profit and loss is blunted. And crony science can beget crony capitalism. When the result sought by crony science has obvious technological implications, then it is no surprise that businesses might see considerable profit opportunity in obtaining government support in pursuing such applications.

In the case of the climate boom, government resources are directed not only to sustaining the boom but also to enlisting a large number of client businesses, who benefit from subsidies that are justified in terms of the businesses' advertised potential for mitigating the effects of human activity purportedly responsible for excessive global warming under the AGW hypothesis. The spillover into the wider economy is manifest in the pervasive emphasis on (and subsidy of) "green energy," including wind power, solar cells, automobile battery technology, and biofuels, and is accompanied by the demonization of more traditional and cheaper carbon-emitting industries and technologies.

As noted in table 3 and the associated discussion, the thrust of government climate-change funding since 2009 has been directed by the executive branch at R&D expenditures for so-called green technologies. The USGCRP under the White House Office of Science and Technology has become the principal agency orchestrating and coordinating climate science funding, but various other agencies, especially the DOE, have administered programs involving direct subsidies, loans, and tax preferences for green technologies.

Section 1705 of the American Recovery and Reinvestment Act of 2009 authorized the DOE to provide taxpayer loan guarantees and direct-investment subsidies for the development of green technologies.[56] As the program wound down in 2014, $16 billion had been allocated to twenty-seven firms. As Christine Lakatos (2014) has

56. Section 1703 of Title XVII of the Energy Policy Act of 2005 (Public Law 109-58) established a Loan Guarantee Program to provide incentives for innovative energy technologies to "avoid, reduce, or sequester air pollutants or anthropogenic emissions of greenhouse gases" and "employ new or significantly improved technologies." Among the categories of "eligible projects," the act lists renewable energy, fossil fuels, and nuclear energy (119 STAT. 1120) (see U.S. Congress 2005). Section 1703 of the American Recovery and Reinvestment Act of 2009 broadened this program to include existing technologies while narrowing the scope of energy sources to renewable and biofuel projects and substantially loosening the eligibility criteria and financing arrangements. See Nava and Morris 2013 for further details.

reported in detail, the majority of the firms had officers or investors with close ties to political insiders at the federal and state levels, campaign bundlers, donors, and DOE agency officials. Of these firms, several have declared bankruptcy, accounting for $3 billion in taxpayer losses,[57] and several others that Victor Nava and Julian Morris (2013) list as "troubled recipients" account for another $3.5 billion.[58] Of the eighteen firms that were not listed as "troubled," fourteen, representing $11.3 billion in loan guarantees, had not completed their projects as of the end of 2013, and only four firms with loan guarantees of $352.6 million had completed projects. In summary, of the $16 billion in DOE loan guarantees, about $15.6 billion represent bankrupt, troubled, or incomplete taxpayer investments as of 2013.

Even if we assume that most of the loan guarantees in the "incomplete" category pan out, the taxpayer losses of perhaps $6.5 billion on a $16 billion "investment" are arguably unacceptable. What accounts for this flouting of conservative stewardship? The most obvious reason is that these investments cannot be ascribed to a market-driven process. Whatever the extent cronyism played in the allocation of these loan guarantees, the entire process was driven by governmental objectives absent market-based constraints and mechanisms.

Beyond these considerations, Nava and Morris (2013) note that 83 percent and 11 percent of the loan guarantees went to solar and wind technologies, respectively, violating basic precepts of investment portfolio diversification and exposing taxpayers ex ante to huge potential risks. In addition, at the outset of the loan-guarantee program, twenty-two of the firms awarded loan guarantees were classified as "junk"-grade investments or lower. As Nava and Morris point out, "[T]he entire portfolio of [Section] 1705 projects has an average rating of BB−, a junk grade rating" (2013, 23).

The effects of Big Player activities in climate science have not been confined to the scientific arena but are being felt in the wider economy. Taxpayer funds are being diverted on a large scale into government-favored businesses whose plans are based on very uncertain science. This is hardly a recipe for economic success; indeed, the performance of such businesses to date would indicate that the entire enterprise is pure economic folly.

Conclusion

The ongoing boom in climate science and its spillover into the wider economy has been made possible by the combination of several mutually supporting factors.

57. Christine Lakatos (2014) calculates the largest amounts of losses (in millions) thus far to have been Solyndra ($570.4), Abound Solar ($494.3), A123 Systems ($390.1), Babcock and Brown ($178), Range Fuels ($162.3), ECOtotality ($135), and Energy Conservation Devices ($110.3).

58. According to Victor Nava and Julian Morris (2013), these firms (with loan-guarantee amounts) are Abengoa ($2.8 billion), Kahuku ($117 million), Nevada Geothermal Power ($98.5 million), and LS Power Associates ($343 million).

The emergence of a scientific Big Player in the IPCC, an organization ostensibly formed to collect and appraise scientific findings about human influence on climate in climate science in a disinterested manner. The IPCC has become a dominant voice in the climate science community, and its summary pronouncements on the state of the science carry significant weight among scientists. But its structure has ensured that it has become more of a political body than a scientific one in that its controlling personnel are political appointees and its summaries are arrived at by a process of negotiated agreement and are vetted and amended by politicians—a process that is the antithesis of science.

The involvement by governments as Big Players, whose activities in lavishly funding the basic science, in enacting restrictive regulation, and in promoting and subsidizing favored "green" enterprises are justified by the claim of scientific consensus regarding the IPCC-promoted AGW hypothesis.

The understandable concern is that if in fact the climate is warming significantly as a result of human action, possible adverse effects of this warming might be mitigated through concerted action. Although this concern rests on three assumptions that are far from certain (that human activity is having a measurable effect on the global climate, that the climate is warming at a rate that will make adaptation difficult and costly for some, and that the effects of warming will be a net negative), it is nevertheless widely held, and it finds powerful (if usually unarticulated) support in the ideological bent that sees humanity as the despoiler of nature.

Scientific booms do burst, but in areas where the phenomena are complex and not well understood, the busts can be quiet and long drawn out. When and how the bust will occur cannot be predicted in advance. It is unlikely (except perhaps in the event of a financial catastrophe) that funding will be cut off. It is more likely that the scientific method will slowly but surely do its work, and the disparity between the predictions of the theory and the observations of a recalcitrant world will become too obvious to ignore. It is also possible that, as happened with eugenics, the political applications of the theory will have effects that will be seen as undesirable or even callously destructive—there are indications already that "green" legislation and regulation are stifling growth and creating unnecessary hardship, especially in Europe.[59]

Nonetheless, on a more hopeful note, science in general and climate science in particular will survive and grow. The science of genetics survived eugenics, and climate science will probably survive the excesses surrounding the AGW hypothesis. The down side is that little will be learned —there appear to be almost no scientists today who identify themselves as eugenicists and, to judge by the biographies of many

59. According to the *Economist* (2014), energy policies in Germany have resulted in the average household now paying an extra $355 a year to subsidize renewable-energy generation and in an unintentional increase in greenhouse-gas emissions. See also, for example, Calzada Alvarez et al. 2010 for an analysis of job destruction by "green jobs" policies in Spain; Hughes 2011 for a similar assessment of policies in the United Kingdom; and Kelly 2014 for a demonstration of how carbon-mitigation policies directly harm the poor.

of the important thinkers of the first half of the twentieth century (when eugenics was considered reasonable science), there were very few serious eugenicists then! But if anything can be learned, it is that in science, as in the economy, Big Players of any sort distort the normal systemic activity, render the emergent outcomes unstable and unreliable, and create an ideal breeding ground for incentives that motivate ideologically biased people to circumvent normal constraints in the name of pursuing a "greater good."

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