

RESEARCH NOTE

The Structure of Scientific Opinion on Climate Change*

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Over the past several decades, environmental issues have become a steadily more significant part of political discourse in the United States and around the world. Since the 1990s, politicians, journalists, and the public have focused increasingly on global climate change, the possibility that human activities are creating significant increases in planetary temperatures. Throughout these debates, the comments of technical experts have played an important part. However, the debate has had an important political dimension, with policymakers either seeking out scientific voices in support of their policies or discounting scientific opinion that failed to support them.

The Obama administration has taken global climate change as a given and has enlisted scientific expertise in developing its policies to combat global warming, a sharp contrast from Republican efforts during the George W. Bush presidency to undermine prevailing theories of climate change (Broder, 2009; Broder & Wald, 2009; Clayton, 2007; Harris, 2008; McCright & Dunlap, 2003; Revkin, 2005, 2006; Rich & Merrick, 2007; Rosenthal, 2009). Ironically, this change in government policy has coincided with increasing public doubt that the scientific community accepts the reality of anthropogenic warming. Researchers at Yale and George Mason University found that the proportion of respondents agreeing that “most scientists think global warming is happening” dropped from 47% in 2008 to only 34% in 2010. Only 5% believe most scientists reject the existence of global warming; a plurality of 40% sees “a lot of disagreement” among scientists (Leiserowitz, Maibach & Roser-Renouf, 2010).

These public doubts could not have been allayed by the 2009 public release of hacked emails from climate scientists at the University of East Anglia, which the popular press dubbed “climategate.” Independent reviews exonerated the scientists of all charges of misconduct or impropriety. Nonetheless, the incident generated

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heavy media coverage and cast a harsh public light on some unseemly aspects of scientific competition and disagreement (Brahic, 2010; Hayward, 2009; Revkin, 2009).

For all the political discord and public uncertainty, there has been relatively little academic examination of scientific opinion regarding global warming and its impact. This research note helps address this relative gap in the literature by presenting data from a survey of prominent scientists affiliated with two professional associations that are closely connected to climate change research—the American Meteorological Society (AMS) and the American Geophysical Union (AGU). In addition to determining the nature of scientific opinion on key issues regarding climate change, we conduct a multivariate analysis to examine some potential determinants of scientific opinion, including nature of employment, professional discipline, level of expertise, and level of confidence in scientific understanding of climate change.

Scientific Opinion on Global Warming

The United Nations-sponsored Intergovernmental Panel on Climate Change (IPCC) has repeatedly stressed that global warming is a serious problem and that governments need to respond to this challenge promptly (Moser & Dilling, 2004; Oreskes, 2004; Rich & Merrick, 2007; Rosenthal & Kanter, 2007; Speth, 2005). However, some scientists have criticized the IPCC for either overstating or understating the extent and effects of climate change. (cf. Keating, 2008; MacFarquhar, 2010; Webster & Pagnamenta, 2010). Expert disagreement and uncertainty is particularly likely when scientists are asked to offer broad conclusions about the rate of global warming and its potential effects, as well as policy suggestions, which involve value-laden and often contentious discussions (Mumpower & Stewart, 1996; Stewart, 1991).

During the past few years, there have been three other systematic surveys of scientific opinion on climate change. A brief survey administered to 3,146 primarily U.S.-based earth scientists in 2008 found 90% agreement that global temperatures have risen since 1800 and 82% agreement that human activity has been a significant factor in this change (Doran & Zimmerman, 2009). The authors report that agreement was highest among respondents who are active in research, and that agreement also varied somewhat according to academic discipline. For example, only 47% of petroleum geologists and 67% of meteorologists surveyed agreed there was human involvement in global warming.

A second study, also conducted in 2008, focused on the authors of journal articles on climate change and members of climate research institutes. This study found that 94% of the 373 respondents believed that climate change is occurring, and 84% attribute recent or near future climate change to anthropogenic causes (Bray & Storch, 2008). However, the authors also reported considerable disagreement over the state of current knowledge and uncertainty about the accuracy of scientific models that offer predictions for future consequences of climate change. For example, respondents were evenly divided over the adequacy of current theoretical understanding of climate change, and fewer than half expressed confidence in the ability of climate models to predict global temperature changes over the next 50 years.

Finally, a survey of 118 German climate scientists in 2006 found that 46% attributed recent climate change mainly to human activities, and 73% believed that human

activities were at least partly involved (Post, 2008). Majorities also expressed doubt that current theoretical understanding and methodological tools were sufficient to accurately predict future climate change.

Taken together, these surveys suggest near-unanimity among the expert community that global warming is occurring and only slightly less agreement that human activity is contributing to this phenomenon. Within the context of general agreement on anthropocentric warming, however, there still appears to be disagreement over the extent and effects of climate change and of the ability of climate science to clarify these issues, based on current theory and available predictive tools.

Data and Measures

Our study addresses some of the same issues as the abovementioned surveys, as well as additional issues not previously addressed, with regard to a universe of climate experts somewhat different from those previously surveyed. In addition, we apply a multivariate analysis toward understanding the sources of opinion differences among scientists. Published reports from previous surveys have been limited to univariate and bivariate data presentations that are mainly intended to identify differences in expert opinion.

In addition, our survey procedures allowed us to address some limitations of previously reported surveys. The two large-scale surveys suffered from the low response rates often associated with online data collection—31% for the Doran–Zimmerman survey and 18% for the Bray–Storch study. In addition, the Doran–Zimmerman survey sampled from listings of the American Geological Institute, a federation of geoscience societies whose member organizations do not include meteorological associations. For example, only 36 of the 3,146 respondents were meteorologists. This is certainly a defensible sample, but it does leave open to question the views of a substantial segment of the climatological community.

For this study, Harris Interactive, an international survey research firm, administered a mail survey among prominent scientists in the United States who were members of the AGU, the professional association of earth and space scientists, or the AMS, the professional association of atmospheric and related oceanic and hydrologic sciences. The sample was drawn equally from members of the AMS and the AGU who were listed in the 23rd edition of *American Men and Women of Science* (AMWS), the most widely recognized biographical reference work on leading American scientists. (Weighting was done to correct for the fact that a respondent belonging to both organizations had a greater chance of being included in the sample.) This procedure secured a survey sample of prominent scientists and ensured that nonscientists—such as student members and, in the case of AMS, media weathercasters—were excluded from the survey.

We searched the online version of AMWS for scientists who listed either the AGU or the AMS among their professional memberships. In AMWS online searches, all selected records are sequentially numbered. We used these numbers to identify which scientist entries to retrieve for the sample. We then used SPSS's random number sampling function to draw the actual samples. A preliminary letter was mailed to 998 respondents, followed by the questionnaire. Two waves of mailings were completed

between March 19 and May 28, 2007. Of the 998 questionnaires, 113 were returned as undeliverable, for an 89% contact rate. Of the remaining 885 respondents, 489 returned completed questionnaires. This represents a response rate of 49% of all eligibles and a cooperation rate of 56% of all contacts.

The survey asked respondents to gauge the current extent and future effects of climate change. First, they were asked whether they believed that global average temperatures has increased over the past 100 years, and whether human-induced warming is now occurring. Then they were asked to estimate the probability that global average temperatures will increase at least two degrees centigrade during the next 50–100 years. That amount is recognized by many scientists and environmental advocates as a threshold beyond which warming will pose grave dangers to the planet (Sheppard, 2009; Wihbey, 2009). Finally, were also asked to rate the seriousness of climate change effects during the next 50–100 years, on a scale ranging from “trivial” to “catastrophic.”

In addition, the survey instrument contained several items on respondents’ backgrounds and attitudes toward the field of climate change, which provide an opportunity to examine some potential sources of variation in scientific opinion. We focused on two sets of potential correlates—the first dealing with professional activities and the second with respondents’ views of the discipline of climate change. With regard to professional activities, the questionnaire asked respondents about their source of employment, area of specialization, and level of expertise, as well as one aspect of their exposure to the “politics” of climate change.

We distinguished among scientists employed in academia, government, and industry. We separated scientists into those specializing in atmospheric and meteorological sciences, those specializing in ocean sciences, geophysics, or geochemistry, and those specializing in other fields, such as ecology. We broke out the subset of those who are currently active in research on global warming. In addition, in light of complaints about intimidation of scientists by government officials (Union of Concerned Scientists, 2007), we identified respondents who said they had been pressured to either downplay or overstate evidence of human-induced global warming.

Several items dealt with how well climate science deals with different aspects of the climate change debate. Respondents were asked how well the scientific community understands climate change, how mature they regard the science of global climate change, and how much confidence they have in current scientific understanding of several factors involved in understanding climate change. Responses to the above are represented by variables labeled “Science Understands,” “Maturity of Climate Science,” and “Confidence Index,” respectively. The last variable consists of an index based on confidence in scientific understanding of the role of the sun’s behavior; the size and extent of the planet’s biomass; archeological climate evidence; the size and extent of anthropogenic sources of greenhouse gases; the impact of volcanoes; natural sources and sinks for greenhouse gases; and the role of positive and negative feedback. A Principal Axis Factor Analysis with Varimax rotation found that all seven questions loaded above .48 on a single factor that explained 40% of the variance. We created a simple seven item additive index ($\alpha = .816$), with high values representing a high level of confidence in these aspects of global warming research.

Although these three variables appear to tap related sentiments regarding the current capacity of current climate science to comprehend global climate change, no other internally valid index combining them could be created. All intercorrelations among the Understands, Maturity and Confidence variables fell below .60. Therefore, we retained all three in the multivariate data analysis, as representing attitudes that are conceptually related but empirically independent.

Results

The responses to the survey questions appear in [Table I](#). Respondents were nearly unanimous in their conviction that global warming is already ongoing, with 97% agreeing that global average temperatures have increased in the past 100 years. There was almost as great a consensus on human-induced warming, with 84% agreeing and only 5% disagreeing that anthropogenic warming is now occurring ([Supplementary Data](#)).

There was greater debate over the likelihood of substantial warming in the near future, with 56% seeing at least a 50–50 chance that temperatures will rise 2% centigrade or more during the next 50–100 years. There was also debate over the seriousness of future effects of global climate change. When asked to rate the effects on a ten-point scale from trivial (1) to catastrophic (10), the mean response was 6.6, with 41% seeing great danger (ratings of 8–10), 44% moderate danger (4–7), and 13% little danger (1–3). Overall, these findings are consistent with previous studies in showing a strong scientific consensus that global warming has been occurring for some time, and that human activities play a role in current warming. Moreover, majorities of scientists foresee a dangerous rise in temperatures in the near future. However, there is still debate over the likely amount and severity of future warming. In short, the demonstrated consensus over anthropogenic warming does not preclude continued debate among scientists over the dangers that this development portends for the future of the planet.

Multivariate Analysis

Given the strong consensus on the existence of anthropogenic warming, we confined our multivariate analysis to the items on which substantial variation in opinion still exists—the projected amount of future warming, and the likely severity of its effects. As shown in [Table II](#), variables that measure an individual scientist's assessment of the status of current climate science were powerful predictors of how likely a scientist thinks temperatures are going to rise globally in the coming decades. The overall weighted least squares regression model has an adjusted R^2 of .287. The three measures that solicit (albeit in different ways) evaluations of the state of climate change research once again all achieved statistical significance. The fourth measure, a dummy variable for employment in a university or college, also predicted more severe estimates of the future effects of climate change. There were no statistically significant findings for whether or not the respondent is employed by government or in business, the area of climate science in which the respondent works, whether he or she is involved in climate research, or was pressured to alter his or her opinions on global warming.

Table I
Scientific Opinion on Climate Change (Results in percentages)

Q: Do you think global average temperatures have increased during the past 100 years?	
Yes	97
No	1
Don't Know	2
Q: In your opinion, is human-induced greenhouse warming now occurring?	
Yes	84
No	5
Don't Know	12
Q: What do you think is the % probability of human-induced global warming raising global average temperatures by two degrees Celsius or more during the next 50 to 100 years?"	
NET values below 50 (%)	19
50-59	8
60-69	4
70-79	10
80-89	12
90-99	17
100	4
NET values 50 or higher	56
Don't Know	26
Mean	63
Q: Overall, if present climate trends continue, do you regard the likely effects of global climate change in the next 50 to 100 years as:	
Trivial to Catastrophic	
1-3 (NET)	13
4-7 (NET)	44
8-10 (NET)	41
Don't Know	2
Mean	6.6

Note: Percentages may not add up to 100 because of rounding error. *Source:* 2007 Harris Interactive survey of American climate scientists; $n = 489$.

Table III examines respondents' estimates of the severity of consequences associated with expected temperature change. This weighted least squares model has an adjusted R^2 of .377, once again largely on the strength of the three measures of attitudes toward climate science, which were all statistically significant once again. Scientists working in higher education anticipated more troubling consequences than did scientists working in other venues.

In addition, perceived pressure to alter one's views had an independent effect on assessments of global warming. Scientists who said they had been pressured to downplay the results of global warming in public rated the likely effects of global warming as slightly less severe than did other scientists. However, in the absence of significant effects for this variable in the other analysis, and the fact that this group constituted

Table II
Weighted Least Squares Regression: Probability of Increased Temperatures Globally, 2007

Variable	Coefficient (<i>b</i>)	<i>SE</i>	β
Science understands	7.80**	2.53	.18
Pressured to downplay	-3.42	5.24	-.03
Pressured to overstate	-2.04	6.74	-.01
Active researcher	2.83	2.82	.05
Maturity of the field	4.14**	1.51	.15
Atmos/Meteor specialist	2.10	3.46	.03
Ocean/Geo specialist	2.19	3.35	.04
Confidence index	2.77***	0.55	.30
University-based	7.80*	3.97	.13
Business-based	0.56	6.67	.004
Government-based	6.37	4.70	.08
<i>n</i>	344		
Adjusted R^2	.287***		
Durbin-Watson	1.94		

Note: * $p < .05$, ** $p < .01$, *** $p < .001$. Dependent Variable: "What do you think is the % probability of human-induced global warming raising global average temperatures by two degrees Celsius or more during the next 50 to 100 years?" Source: 2007 Harris Interactive survey of American climate scientists.

only 5% of the sample, one should be cautious in interpreting the substantive significance of this finding.

Conclusion

Our findings generally but not entirely support those of other recent surveys of scientific opinion on climate change. They also add to our overall knowledge of what climate experts believe about global warming and why their beliefs sometimes differ. In keeping with Doran and Zimmerman's survey of earth scientists, our respondents were almost unanimous in believing that global temperatures have increased during the past century and that current warming, at least, has anthropogenic origins. In keeping with both Post's and Bray and Storch's surveys, we found a strong consensus that human-induced warming is now occurring, along with greater diversity of opinion over future climate change and the capacity of climate science to accurately measure and explain it.

The multivariate analysis further enriched our understanding of the dynamics of the debate, while raising some additional questions. For example, disciplinary differences may help explain why our respondents were less likely than those surveyed by Doran and Zimmerman to ascribe past warming to human activity. A specialization in earth sciences was a predictor of this position, relative to the atmospheric and meteorological specializations that were less prominent in the earlier sample. Greater representation of the latter groups would help account for the greater diversity of opinion that we found on the causes of past warming. However, this independent

Table III

Weighted Least Squares Regression: Consequences of Increased Temperatures Globally, 2007

Variable	Coefficient (<i>b</i>)	<i>SE</i>	β
Science understands	.93***	.15	.30
Pressured to downplay	-.76*	.33	-.09
Pressured to overstate	-.66	.41	-.06
Active Researcher	-.06	.17	-.01
Maturity of the field	.28***	.09	.14
Atmos/Meteor specialist	-.18	.20	-.04
Ocean/Geo specialist	-.26	.20	-.06
Confidence index	.14***	.03	.24
University-based	.68**	.23	.14
Business-based	-.10	.37	-.01
Government-based	.43	.27	.08
<i>n</i>	458		
Adjusted <i>R</i> ²	.377***		

Note. * $p < .05$, ** $p < .01$, *** $p < .001$. Dependent Variable: "Overall, if present climate trends continue, do you regard the likely effects of global change in the next 50 to 100 years as ranging from (1) trivial to (10) catastrophic?" *Source:* 2007 Harris Interactive survey of American climate scientists.

effect of academic specialization on attitudes did not extend to questions involving the future impacts of climate change.

We had expected that industry-based scientists might be less concerned about the effects of global warming, as a result of acculturation into a relatively conservative or business-oriented work environment (Lynn, 1986). This expectation also reflected a public debate in which political conservatives and some business interests (particularly in the energy industry) have opposed government legislation and regulation intended to mitigate the effects of climate change, while liberals and environmental groups have supported such measures (Achenbach, 2006; McCright & Dunlap, 2003). However, the multivariate analysis revealed no independent effect of industry employment on scientific attitudes toward climate change.

In contrast, scientists who worked in academic settings were more pessimistic about the rate and effects of global warming. Even after other variables have been taken into account, scientists in academia were more likely than those in government or business to believe that global temperatures are likely to rise substantially in the future, and that the consequences will be particularly severe. This finding raises important questions about the applicability of a "sociology of knowledge" perspective to scientific controversies (Berger & Luckmann, 1967; Mazur, 1981; Mazur, Rothman, & Lichter, 2001).

In any event, none of these background variables was as useful in explaining opinions on the causes and effects of global warming as was the level of confidence in the methods and findings of climate science. Our respondents did not differ so much in their conclusions about climate change as in the amount of credence they attached to

any conclusion, based on our current knowledge and methods of inquiry. Thus, the multivariate analyses consistently revealed that the more faith or confidence scientists had in the work being done by their colleagues, the more concerned they were about global warming and its effects.

On the whole, our findings suggest that the dynamics of scientific opinion on climate change hinge on questions of method. They provide little support for criticisms that scientists' views on global warming are based on workplace pressures or desires to further their own careers or expand their public influence. We found disagreement over the future effects of climate change, but not over the existence of anthropogenic global warming. Indeed, it is possible that the growing public perception of scientific disagreement over the existence of anthropogenic warming, which was stimulated by press accounts of "climategate," is actually a misperception of the normal range of disagreements that may persist *within* a broad scientific consensus.

Future researchers might conduct studies of expert opinion in this area to help further illuminate the nature of scientific opinion and the potential trajectory of future discourse in this contentious area of public policy. In addition, future surveys might include more demographic and background measures, so that we can see more closely whether the factors that affect public opinion generally also help explain differences among scientific experts.

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Supplementary Data

Supplementary Data are available at *IJPOR* online.

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