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The elusive consensus on climate change

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Abstract: Thirteen studies quantify the agreement that climate change is real and human-made. Consensus is at odds with the scientific method and irrelevant for policy. Respondents with little relevant expertise and papers on loosely related subjects dominate the studies. Data are analyzed with insufficient care, and samples arbitrarily restricted. Combining estimates from different studies, 89% agree that human activity significantly affected climate after 1750, and 80% that humans were the most important driver of climate change. 97% agree that human activity was the most important factor in climate change since 1950, but only 80% that anthropogenic greenhouse gases were.

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Abstract

Thirteen studies quantify the agreement that climate change is real and human-made. Consensus is at odds with the scientific method and irrelevant for policy. Respondents with little relevant expertise and papers on loosely related subjects dominate the studies. Data are analyzed with insufficient care, and samples arbitrarily restricted. Combining estimates from different studies, 89% agree that human activity significantly affected climate after 1750, and 80% that humans were the most important driver of climate change. 97% agree that human activity was the most important factor in climate change since 1950, but only 80% that anthropogenic greenhouse gases were.

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1. Introduction

President Barack Obama tweeted that 97% of climate scientists agree: Climate change is real, man-made and dangerous.¹ This meme has been repeated time and again, often in an attempt to shut down debate on the necessity of climate policy (Howarth and Sharman, 2015). The reasoning itself is fraught. The desired intensity of climate policy follows from a careful consideration of its costs and benefits, and the uncertainties around both, rather than from the strength of agreement² on something that is one-step removed from the benefits (Pearce et al., 2017, see also Cook (2017)). What matters is not whether the alleged dangers

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¹See Obama (2013).

²Some have argued that the majority of experts have been wrong before. This is true, and there is no reason to assume that this cannot happen again. However, we should make decisions based on the best evidence available at the time. Grundmann (2016) emphasizes that climate policy will frequently alter course as new information arises and priorities change.

of climate change are real, but whether climate policy takes away those dangers at an acceptable cost. The appeal to scientism is fallacious (Blue, 2018) but popular and perhaps effective: Although some studies show that people respond to cues about the scientific consensus³ (Guy et al., 2014, Myers et al., 2015, van der Linden et al., 2014, van der Linden, 2015, van der Linden et al., 2015), other papers show that this effect is dominated by other factors (Bliuc et al., 2015, Campbell and Kay, 2014, Kahan, 2015, Hamilton, 2016, Uscinski and Olivella, 2017, Benegal, 2018, Benegal and Scruggs, 2018, Bolsen and Druckman, 2018, Chinn et al., 2018, Hartter et al., 2018, Linde, 2018, Newman et al., 0, Tom, 2018). In this paper, I examine the evidence behind the meme that 97% of climate scientists agree that climate change is real, human-made and dangerous.

The third part of the meme is easily discarded. President Obama referred to an article by Reuters,⁴ which does not include the words “danger” or “dangerous”. The Reuters article reports on a paper in a learned journal that does not contain those words either (Cook et al., 2013). The “dangerous” part of the meme is embellishment by a politician.⁵

Scientists do not agree on what constitutes “dangerous” climate change (Parry et al., 1996, Schneider, 2001, Dessai et al., 2004, Oppenheimer, 2005, Smith et al., 2009, Hansen et al., 2013). They cannot agree, because “danger” is not a scientific term. There are agreed, but essentially arbitrary standards on the safety of food and medicine. Products are scientifically tested to these standards in controlled experiments with animals and, for medicine, controlled trials with small samples of human subjects. Even if we could agree on what would constitute “safe climate change” (cf. Hulme, 2009), we cannot conduct equivalent trials and experiments.

Declaring something to be dangerous is a value judgement, and thus beyond the domain of scientific inquiry. Individuals can decide what is an acceptable risk to themselves, but have great difficulty with estimating probabilities (Lichtenstein et al., 1978). Individual preferences on what is dangerous climate change (Leiserowitz, 2005) do not aggregate to social preferences (Arrow, 1950, Tol and Yohe, 2006). Studies of what is considered dangerous by society reveal patterns of risk amplification and suppression, only loosely connected to the objectively estimated impacts and probabilities (Beck, 1996).

It is often argued that a global warming of 2°C or more would be dangerous (Oppenheimer and Petsonk, 2005, Tol, 2007, Jaeger and Jaeger, 2011, Knutti et al., 2016). This is a political target, indeed part of the Paris Agreement under the United Nations Framework Convention on Climate Change. The 2°C target originates in a 1995 report by the Scientific Advisory Council Global Environmental Change of the Federal Government of Germany (WBGU, 1995), a committee of 11 German professors. It rests on three arguments. First, it aims to safeguard creation, a peculiar reason for a scientific council of a secular government. The WBGU refers to the range of global temperatures since the emergence of

³See Hamilton et al. (2015) for a review of public opinion on climate change. See Beebe et al. (2019) for a survey of climate scientists’ view on consensus.

⁴See Doyle (2013).

⁵Similarly, the paper concludes that 97% of climate scientists thinks that climate change is real and human-made, but does not single out males. Obama’s casual misandry is regrettable.

modern humans. This is the *is-ought fallacy* of [Hume \(1740\)](#) and the *naturalistic fallacy* of [Moore \(1903\)](#).⁶ By the same reasoning, we should be concerned about high levels of life expectancy, literacy and women’s rights, all of which are decidedly outside their historical ranges. It also ignores the generally accepted view that humans evolved in the subtropics and later migrated to temperate climates. The second argument by the WBGU is that 2°C warming would cause economic damages of 5% of GDP, a view that is not supported by the literature and was not at the time ([Tol, 2016b](#)). WBGU further claims that drastic ecological impacts could be expected if more warming were to happen, a claim that was far beyond the state of ecological research at the time. The 2°C target was adopted by the German government in the same year, and a year later without much discussion by the Council of the European Union. The 2°C target was reaffirmed by the Council of the European Union in 2004, as preparations for a successor treaty to the Kyoto Protocol began. It was the only long-term, global target, and thus became a focal point for the 2007 Fourth Assessment Report of the Intergovernmental Panel on Climate Change. The 2°C was agreed in 2010 at the international climate negotiations in Cancun.

The rest of the 97% meme requires more careful consideration. There have a number of so-called consensus studies. [Cook et al. \(2016\)](#) argues that there is a consensus on the consensus, and that all consensus studies agree with [Cook et al. \(2013\)](#). This is not the case. In Section 2, I review the methods used in these papers. In Section 3, I assess the results. Section 4 concludes that the 97% meme is based on weak data and that agreement on precise statements is lower.

2. Consensus studies

Different consensus studies examine agreement on different issues:

- Climate change is mostly the result of anthropogenic causes ([Bray and von Storch, 2007, 2010](#), [Rainie and Funk, 2015](#)).
- Global warming is mostly caused by humans ([Stenhouse et al., 2013](#)).
- Human activity is a significant contributing factor in changing mean global temperatures ([Doran and Zimmerman, 2009](#), [Carlton et al., 2015](#)).
- Is the warming measured over the past 100 years within the range of natural, not human-induced, fluctuations ([Lichter et al., 2015](#))?
- Most of the warming in the second half of the 20th century is caused by greenhouse gas emissions ([Oreskes, 2004](#)).
- It is very likely that most of the warming in the second half of the 20th century is caused by anthropogenic greenhouse gas emissions ([Anderegg et al., 2010](#)).

⁶Environmentalism is one of the three offshoots of Romanticism ([Miller, 2005](#), [Hinchman and Hinchman, 2007](#)), and shares its idealization of the past.

- Humans are the primary cause of recent global warming ([Cook et al., 2013](#)).
- More than half of global warming since the mid-20th century can be attributed to human-induced increases in atmospheric greenhouse gas concentrations ([Verheggen et al., 2014](#)).
- Is human-induced greenhouse warming now occurring ([Lichter et al., 2015](#))?
- Scientists can say with great certainty that human activities are accelerating global warming ([Rosenberg et al., 2010](#)).

Some studies focus on greenhouse gases, others on all human impacts on climate (including, e.g., aerosol emissions, land cover change, urbanization). Some studies focus on some human contribution to the observed warming, others on the main cause. Some studies refer to any (presumably recent) climate change, others to the second half of the previous century. Answers to these questions need to be compared with care.

Table 1 provides information on sample sizes and respondent characteristics. The attribution of observed climate change to its potential causes occupies a select group of climatologists and statisticians, who, based on their expertise, can provide an expert opinion on the question whether human activity is a major cause of the observed global warming. The consensus studies, however, did not limit their sample to acknowledged experts, or even sought to oversample these researchers. Instead, the larger group of climate scientists, geoscientists, natural scientists, or even natural and social scientists were surveyed. [Carlton et al. \(2015\)](#), for instance, surveyed 698 researchers, only 38 of whom worked primarily on climate change. [Doran and Zimmerman \(2009\)](#) surveyed 3146 experts, only 79 of whom are climate scientists. Academics tend to be quite critical about work in their own, narrow field of specialization and often strongly disagree with their peers. However, outside their immediate expertise, academics may follow the received wisdom or demonstrate their ignorance. Surveying researchers in adjacent fields and cognate disciplines would thus be likely to lead to confirmation bias and noisy data.

[Verheggen et al. \(2014\)](#) is the only study that separately studies attribution specialists and other researchers. 74% of experts argue that more than half of recent warming is due to greenhouse gases, compared to 66% of all respondents. 83% of respondents argue that greenhouse gases have a strong or moderate warming effect, but 8% blame natural variability and 12% the sun, while a further 11% argue that the observed temperatures are spurious—that is, a substantial fraction of the respondents appear to hold mutually exclusive beliefs.

[Carlton et al. \(2015\)](#) found similar inconsistencies. They put three statements to the respondents. 71% disagree that “[v]ariation in solar activity is responsible for the majority of the observed warming in the past century.” 96% agree that “[h]igher emissions of greenhouse gases will lead to greater atmospheric warming.” Intriguingly, 8.4% agree with the first and second statement. According to Stuart Carlton (personal communication, 23 Nov 2015), “[i]t’s hard to know precisely what those 53 people [...] were thinking”. 89% disagree that “[c]limate change is independent of atmospheric carbon dioxide levels”. Comparing the

study	year	method	sample
Lichter et al. (2015)	1991	survey	400 AGU/AMS members
	2007	survey	489 AGU/AMS members
Bray and von Storch (2007)	1996	survey	539 climate scientists
	2003	survey	530 climate scientists
Oreskes (2004)	2004	other-rated abstracts	928 papers
Bray and von Storch (2010)	2008	survey	370 climate scientists
Doran and Zimmerman (2009)	2008	survey	3146 earth scientists
Anderegg et al. (2010)	2009	public statements	1372 climate scientists
Rosenberg et al. (2010)	2005	survey	468 US climate scientists
Cook et al. (2013)	2012	other-rated abstracts	11944 papers
		self-rated abstracts	2142 papers
Stenhouse et al. (2013)	2012	survey	1821 meteorologists
Verheggen et al. (2014)	2012	survey	1868 climate scientists
Carlton et al. (2015)	2014	survey	698 biophysicists
Rainie and Funk (2015)	2014	survey	1627 working PhD scientists
Bray and von Storch (2016)	2015	survey	658 climate scientists

Table 1: Studies of agreement on climate research.

second and third statement, 34 respondents argued that carbon dioxide has no impact of climate, but at least 3 of those 34 argue that greenhouse gases do. In every survey, there is a fraction of respondents who give nonsensical answers. These entries should be removed or flagged during data cleaning.

The first high-profile consensus study, Oreskes (2004), found that, three-quarters of papers agree that most of the warming in the second half of the 20th century is caused by greenhouse gas emissions and none disagree, a likely result of sample selection bias. Peiser (2005) contends that Oreskes’ work suffers from confirmation bias too, as many of the surveyed paper do not say what she claims they say.

The most influential of consensus studies, Cook et al. (2013), has a number of methodological problems (Reuswig, 2013, Tol, 2014a, Cook et al., 2014a,b, Tol, 2014b, Legates et al., 2015, Dean, 2015, Cook and Cowtan, 2015, Tol, 2016a, Cook et al., 2016). These include:

- Cook uses an **unrepresentative sample**. Their selection of 12,000 papers does not match the larger literature in its disciplinary composition, undersamples papers by the most prolific authors, and oversamples the most heavily cited papers.
- Cook uses **low quality data**, with an estimated 6.7% of incorrect entries.
- Cook used **invalid data**. Abstract ratings disagree with paper ratings in 63% of cases.
- There are **inexplicable patterns** in Cook’s data, which were collected over a period of months, with chronological ratings drifting to and fro skepticism in a way that is

inconsistent with Cook’s claim that papers were rated in a random order, and is not inconsistent with confirmation bias.

- There are **systematic differences between raters** while rater attrition is not random.

Cook’s main flaw, perhaps, is that the majority of the investigated papers that take a position on the causes of climate change in fact do not examine any evidence. These are papers on the impacts of climate change or on climate policy. These papers merely repeat the standard position in climate change. Unsurprisingly, papers in climate science narrowly defined are considerably more skeptical about the causes of climate change than papers in climate impacts and climate policy.

3. Consensus on consensus

Figure 1 shows the share of respondents agreeing with a statement that roughly corresponds to climate change being real and human-caused, by year of publication and sample size. The figure shows many results above 80% but also much lower estimates. There clearly is no consensus on the consensus.

Figure 1 excludes those respondents who did not have a position or felt uncomfortable taking one. Figure 2 includes those respondents. Sample sizes go up and consensus rates down. Figure 2 further highlights the disagreement on what fraction of experts or papers agreeing that climate change is real and human-made.

One can dismiss the results of Figure 2 as it includes those who felt uncomfortable expressing an opinion. However, the consensus studies did not survey a random group of people or papers. Instead, a specific group was targeted, precisely because this group (in the eyes of the authors of the consensus studies) had something useful to say about the reality of anthropogenic climate change. At the very least, therefore, Figure 2 reveals something about the ineffectiveness of the pre-screening that led to the sample selection.

Figures 1 and 2 also show the results for subsamples, selected by the authors of the original studies. Careful selection of respondents can increase the estimated consensus rate but, as for every more-consensus-minded subsample there is less-consensus-minded complement, reduce the consensus rate too.

3.1. Monotonicity

As noted above, the different consensus studies asked different questions. This allow us to test for monotonicity. Some people may argue that land use change is the primary cause for the observed warming, and others may argue that greenhouse gases are. The question “are human responsible ...” should therefore find more agreement than the question “are greenhouse gas emissions responsible ...”. Questions on climate change can be ordered from high to low agreement as follows:

1. Human activity is a significant contributing factor in changing mean global temperatures (Doran and Zimmerman, 2009, Carlton et al., 2015).

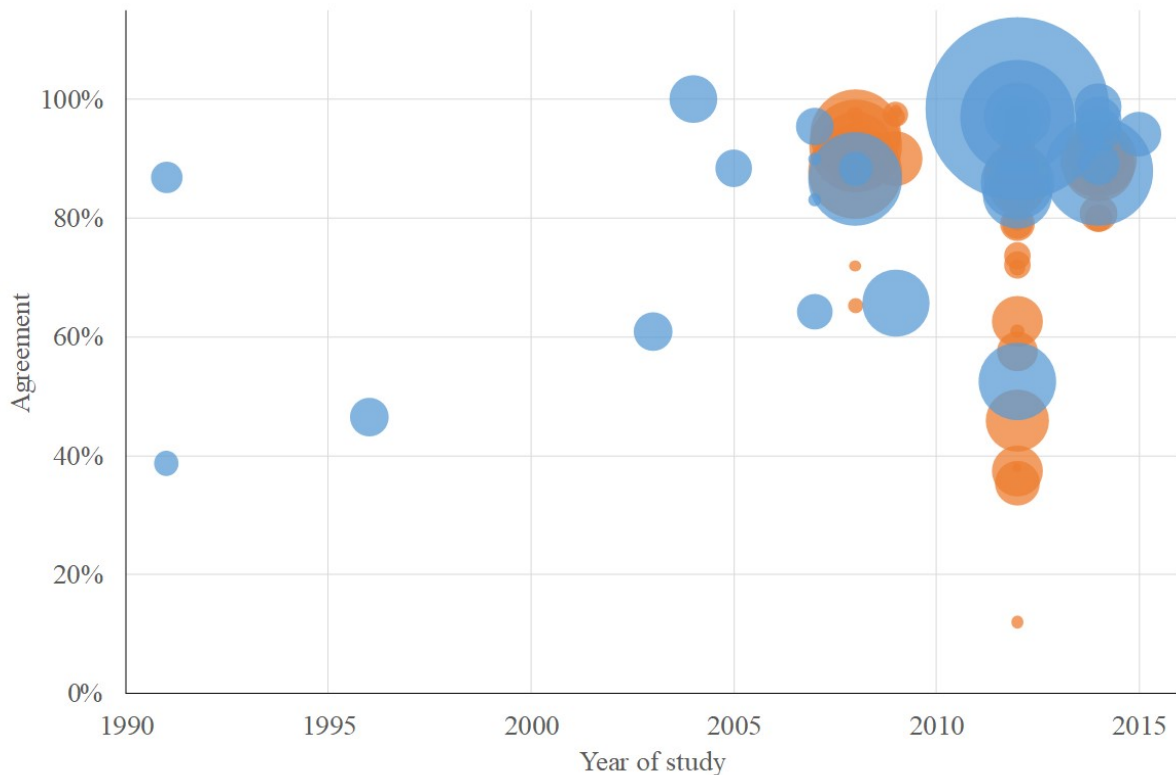


Figure 1: Agreement to the statement that climate change is real and human-made (vertical axis) by publication year (horizontal axis) and sample size (bubble area), excluding don't knows, full samples are in blue, subsamples in orange.

2. Climate change is mostly the result of anthropogenic causes (Bray and von Storch, 2007, 2010, Stenhouse et al., 2013, Rainie and Funk, 2015, Bray and von Storch, 2016).

Table 2 shows that respondents are indeed more inclined to agree to the weaker statement on significance than to the stronger statement on significance and effect size.

Questions on recent climate change can be ordered from high to low agreement as follows:

1. Humans are the primary cause of recent global warming (Cook et al., 2013).
2. Most of the warming in the second half of the 20th century is caused by greenhouse gas emissions (Oreskes, 2004, Anderegg et al., 2010, Verheggen et al., 2014).

Table 2 shows that respondents are indeed more inclined to agree to the weaker statement on human activity than to the stronger statement on anthropogenic greenhouse gas emissions.

4. Discussion and conclusion

I review 13 studies that quantify the consensus rate among experts, the level of agreement that climate change is real and human-made. This attempt is misguided as science

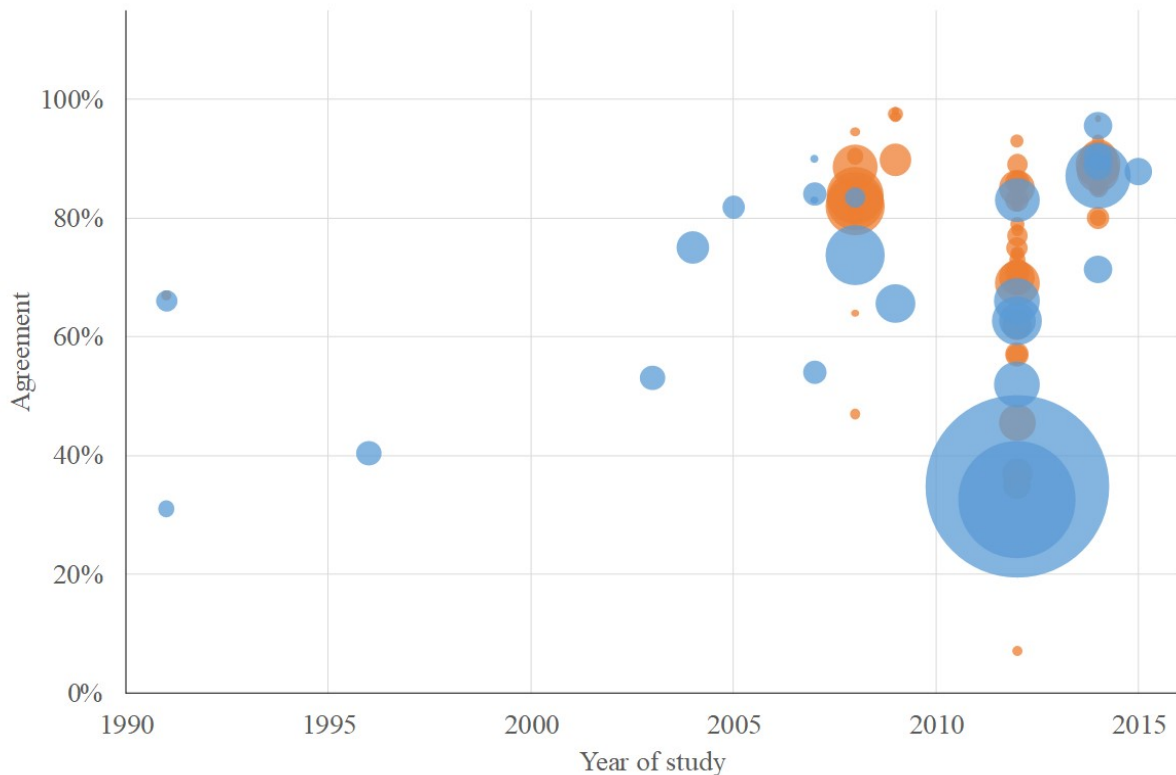


Figure 2: Agreement to the statement that climate change is real and human-made (vertical axis) by publication year (horizontal axis) and sample size (bubble area), including don't knows, full samples are in blue, subsamples in orange.

is organized skepticism and scientific agreement largely irrelevant to policy. The 13 papers study different things. Survey respondents find it easier to agree that human activity had a *significant* effect than that this effect was *larger than other influences*. Respondents more readily agree that *human activity* had an effect than that *greenhouse gases* had an effect. Surveys are dominated by respondents with little relevant expertise and by papers on loosely related subjects. Data are analyzed with insufficient care. Headline conclusions appear to be driven by arbitrary choices about the inclusion of responses. Taken the studies at face value, there appears to be 89% agreement that human activity significantly affected climate after 1750, with 80% agreeing that humans were the most important driver of climate change. 97% agree that human activity was the most important factor in climate change since 1950, but only 80% that anthropogenic greenhouse gases were.

The impact of greenhouse gas emissions on the global climate should not be studied by counting noses. The effect is determined by the climate sensitivity, the equilibrium global warming due to a doubling of the atmospheric concentration of greenhouse gases. If the climate sensitivity is zero, greenhouse gases had no impact in the past and will not in the future. Many estimates of the climate sensitivity have been published, using a variety of methods and data (Knutti and Hegerl, 2008, Bindoff et al., 2013). These studies entertain

climate change since 1750	human activity		
	significantly 88.5% (87.4%-89.5%)	mostly 80.4% (79.1%-81.7%)	
climate change since 1950	mostly		
	human activity 97.1% (96.6%-97.6%)	greenhouse gases 80.1% (78.7%-81.4%)	

Table 2: Combined estimates of the consensus rate for four alternative statements.

Note: Central estimates are the weighted average of the consensus rates, excluding don't knows, in the relevant studies, using the sample sizes as weights. In between brackets are the bootstrapped 95% confidence intervals.

the hypothesis that the climate sensitivity is zero, and firmly reject it.

It is an academic question, not a policy one, whether—and if so since when—greenhouse gas emissions have been the most important driver of observed climate change. As future greenhouse gas concentrations are projected to be much higher than past concentrations, anthropogenic climate change is bound to become larger, both absolutely and relative to other factors. The question whether climate change can best be mitigated by greenhouse gas emission reduction or, say, alleviating the urban heat island effect (Estrada et al., 2017) is not just a matter of their relative contributions to warming, but also of the relative costs of these countermeasures and the feasibility of their implementation.

Empirical studies referred to in the introduction suggest that there is at most a weak impact of academic consensus on attitudes to climate policy. In sum, attempts to quantify the consensus on climate change are misguided, unconvincing, and ineffective.

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