nature climate change

ARTICLES
https://doi.org/10.1038/s41558-019-0564-z

Climate experts' views on geoengineering depend on their beliefs about climate change impacts

Astrid Dannenberg* and Sonja Zitzelsberger

Damages due to climate change are expected to increase with global warming, which could be limited directly by solar geoengineering. Here we analyse the views of 723 negotiators and scientists who are involved in international climate policy-making and who will have a considerable influence on whether solar geoengineering will be used to counter climate change. We find that respondents who expect severe global climate change damages and who have little confidence in current mitigation efforts are more opposed to geoengineering than respondents who are less pessimistic about global damages and mitigation efforts. However, we also find that respondents are more supportive of geoengineering when they expect severe climate change damages in their home country than when they have more optimistic expectations for the home country. Thus, when respondents are more personally affected, their views are closer to what rational cost–benefit analyses predict.

As international climate policies have so far been unable to stop and reverse the trend of rising global GHG emissions[1], solar geoengineering is increasingly gaining attention. In particular, it is discussed as a way to bridge the time until clean technologies are developed and implemented and to respond in case of a climate emergency[2,3]. Solar geoengineering, or solar radiation management, aims to cool the Earth's surface temperature to counter climate change by partially deflecting the incoming sunlight. The most prominent proposal is to inject aerosol particles into the lower stratosphere to increase deflection of sunlight. Other ideas involve cloud brightening, the deployment of space mirrors, or whitening of rooftops. Solar radiation management could have a rapid effect on temperature and it would be relatively cheap[4–6]. The main concern is about the risks and side effects, such as a chemical ozone loss at high latitudes[7,8], changes in regional precipitation patterns[9] or the consequences of abrupt determination[10,11]. In some cases, geoengineering is defined more broadly to also include CO_2 removal technologies, such as ocean iron fertilization, biomass energy with carbon capture and storage, enhanced weathering and direct-air capture with storage. However, these technologies are very different from solar radiation management. The costs of deploying these technologies are relatively high and the resulting effects on the climate are very slow, making these technologies unsuitable for an emergency response[11–15] (see Supplementary Note 1 for more details).

Governments around the world have adopted a wait-and-see approach so far. None of the major economies has officially endorsed or rejected solar geoengineering as a strategy to fight climate change, yet most of them invest in research into geoengineering. The Convention on Biological Diversity has invited its 196 parties to abstain from using geoengineering that may affect biodiversity until there is an adequate scientific basis. The Paris Agreement on climate change does not mention solar geoengineering. A recent proposal by Switzerland and ten other countries that the UN Environment Programme prepares a comprehensive assessment of geoengineering, including rules on research and deployment, was rejected by the United Nations Environment Assembly[16].

Scientists have studied the potentials and limitations of solar geoengineering technologies[17–19]. The latest reports by the IPCC include solar geoengineering[11,20], showing that it is becoming a part of mainstream climate science. Social scientists have studied how the technologies are perceived by the public[21–26], activists[27–29] and the media[30]. This research consistently finds that public awareness and knowledge about solar geoengineering technologies are low[25,31] and at least the initial support tends to be low[32,33]. Research on geoengineering is more readily accepted than deployment[25,31,32]. Assessments are very sensitive to the provided information[34,35] and there is concern that geoengineering deflects efforts to reduce emissions, especially among policy-makers, activists and researchers in developing countries[22,24,36]. Two large-scale surveys with citizens living in the United Kingdom and Germany find higher support of geoengineering among those who are concerned about climate change[37,38]. Economic cost–benefit analyses show that solar geoengineering can be part of an optimal policy portfolio, especially if the expected temperature increase and the corresponding damages without solar geoengineering are high. Uncertainty about climate sensitivity—the increase in temperature from a doubling of CO_2 concentrations—increases the use of solar geoengineering. Severe side effects of solar geoengineering and uncertainty about those side effects limit its use in some scenarios to a climate emergency only[39–42].

In this paper, we investigate how experts involved in the diplomatic and scientific efforts relating to climate change assess solar geoengineering. Our analysis is based on data from a worldwide survey (see Methods and Supplementary Methods) with 723 respondents from more than 150 countries. Participants were recruited from the two main institutions that the international community has established to address climate change: the United Nations Framework Convention on Climate Change (UNFCCC) and the IPCC. The views of this group of experts have not been studied before, even though they arguably have a bigger influence on the role that solar geoengineering will have to address climate change than previously studied groups. Using a standardized online questionnaire, we asked the experts about their views on three aspects of geoengineering: how important it is to include geoengineering in the climate negotiations, whether more investment should be directed to research and development (R&D) on geoengineering technologies and whether geoengineering technologies should be deployed in the event of an approaching climate emergency that

Department of Economics, University of Kassel, Kassel, Germany. *e-mail: dannenberg@uni-kassel.de

could not be avoided by means of conventional mitigation techniques. We also elicited a number of other attitudinal and personal characteristics that potentially affect the views on geoengineering, including expectations about the effectiveness of current mitigation efforts and climate change impacts. We distinguish between expectations about global climate change impacts, representing the perceived severity of climate change for humankind in general, and expectations about impacts in the home country of the respondents, representing more personal consequences of climate change. The difference between the global perspective and the home country perspective has been ignored so far and it turns out to be very important for the assessment of geoengineering.

Respondents' expectations about climate change impacts

Figure 1 shows that the expectations of respondents about climate change impacts in their home country and the estimations of the impacts in that country according to a recent study by Burke, Hsiang and Miguel (BHM)[43] are positively correlated (Pearson correlation test, $r=0.33$, $P<0.01$, $n=634$). Respondents from countries for which high damages are predicted tend to expect higher damages, whereas respondents from countries for which low damages or gains are predicted tend to expect lower damages. The correlation is stronger if we disregard the seven respondents who expect positive consequences of climate change ($r=0.36$, $P<0.01$, $n=627$). Using a different measure for the vulnerability of each country to climate change, namely the ND-GAIN index for the year 2015, we also obtain a significant positive correlation between respondents' expectations for their home country and the index value for that country ($r=0.39$, $P<0.01$, $n=623$). The ND-GAIN index is compiled by the Notre Dame Global Adaptation Initiative and combines different measures of vulnerability to climate change with measures of adaptive capacity.

We also estimate an ordered probit model with the expectations of the respondents as the dependent variable and the BHM forecast of the impacts as the main explanatory variable. The regression results are shown in Supplementary Table 1. The results show that the BHM estimations have a significantly positive effect on the expectations of the respondents ($P<0.01$), confirming that the expectations of the respondents correspond to recent projections, albeit not perfectly. Separate analyses for the IPCC sample and the UNFCCC sample to compare the BHM estimations and the expectations of the respondents show similar results (Supplementary Table 1).

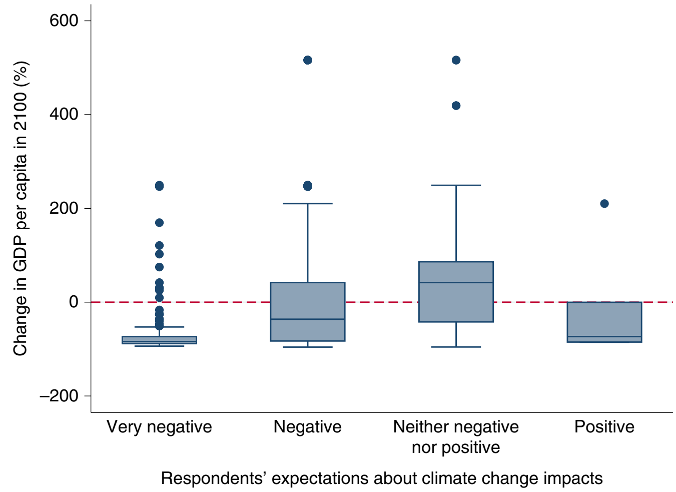

Fig. 1 | Scientific estimates and expectations of the respondents of climate change impacts in their home country. The distribution of the BHM estimations of changes in GDP per capita in 2100 due to climate change in the home country of each respondent separated by the respondents' own expectations of climate change impacts in 2100 for their home country. The boxes include the 25th and 75th percentiles of the estimated change in GDP, with the median depicted as a horizontal line within the box. The whiskers extending from the boxes include all data points within 1.5× the interquartile range of the nearer quartile. The dashed red line divides the BHM estimations in gains and losses from climate change. The number of observations for expected 'positive' consequences for the home country is very low ($n=7$). The number of observations for the other categories are (from left to right): $n=190$, $n=342$ and $n=95$.

Respondents' views on geoengineering

Respondents are almost evenly divided in their views on geoengineering. In total, 42% of respondents consider it important to include the issue of geoengineering in the international climate negotiations, 53% do not consider this important and 5% do not know ($n=719$). In addition, 50% of participants think that more investments should be directed to R&D in geoengineering technologies while 43% do not agree with this statement and 7% do not know ($n=711$). Finally, 52% support large-scale deployment of

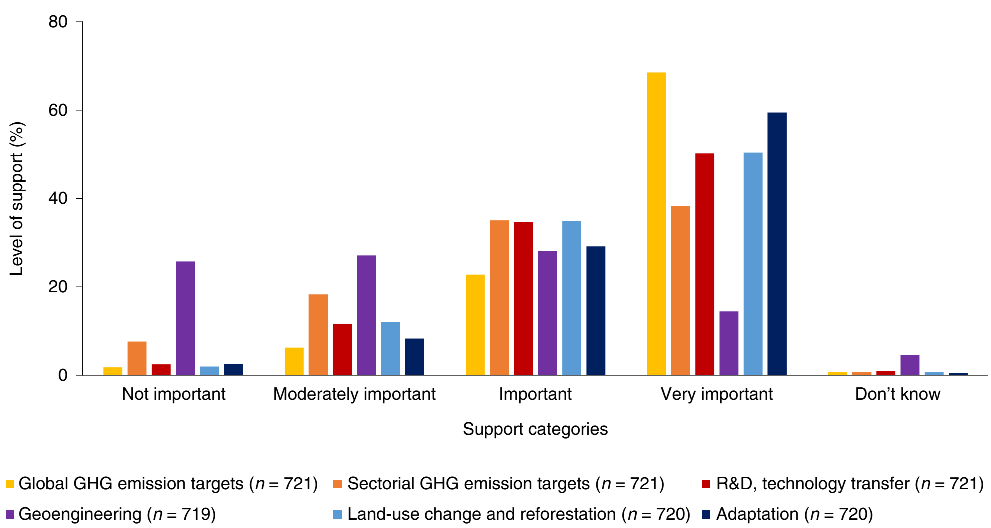

Fig. 2 | Comparison of geoengineering with conventional mitigation and adaptation. The categorical percentages for each answer to the question 'How important do you think it is to include the following issues in current international climate change negotiations?' for six issues.

Table 1 | Results of binary probit regression testing support for including geoengineering in international climate negotiations

Variable	Model			
	(1)	(2)	(3)	(4)
	Supportive	Supportive	Supportive	Supportive
Percentage loss in GDP in 2100	0.19***	0.11		
	(2.72)	(1.35)		
Percentage gain in GDP in 2100	−0.03	−0.02		
	(−0.99)	(−0.71)		
Expect severe home country damages (d)			0.11**	0.06
			(2.12)	(1.25)
GDP per capita		−0.03*		−0.05***
		(−1.90)		(−3.55)
Expect severe global damages (d)	−0.11***	−0.11***	−0.16***	−0.14***
	(−2.82)	(−2.73)	(−3.61)	(−3.24)
CO_2 per capita	1.56	8.88	−2.16	10.92*
	(0.37)	(1.59)	(−0.49)	(1.94)
Optimistic about GHG reductions	−0.02	−0.02	−0.03	−0.02
	(−0.60)	(−0.50)	(−0.71)	(−0.43)
Optimistic about INDCs	0.07**	0.07*	0.08**	0.06*
	(2.00)	(1.82)	(2.04)	(1.69)
Negotiation scope	0.32***	0.31***	0.33***	0.30***
	(7.47)	(7.17)	(7.60)	(6.82)
IPCC (d)	−0.09	−0.07	−0.07	−0.05
	(−1.56)	(−1.33)	(−1.21)	(−0.81)
Controls included	Yes	Yes	Yes	Yes
Observations	492	491	447	446

The numbers show binary probit estimations of average marginal effects (discrete effects for dummy variables) and *z* values in parentheses. The models are estimated with maximum likelihood, using heteroscedasticity robust standard errors. The stochastic component in the models is assumed to be normally distributed. The dependent variable is a dummy, taking the value of 1 if an individual response is categorized as supportive of geoengineering and 0 otherwise. Models (1) and (2) account for region-specific climate change impacts using the BHM estimations whereas models (3) and (4) use expectations of respondents. Models (2) and (4) additionally control for GDP per capita in the home country of the respondent. $*P < 0.10$, $**P < 0.05$, $***P < 0.01$. d, dummy variable. Variables included as controls but not shown: gender, age, training and employer organization. INDCs, Intended Nationally Determined Contributions.

geoengineering in the event of an approaching climate emergency, 30% do not support such a response and 18% do not know ($n = 705$). Assessments of the three aspects are positively correlated (the correlation coefficients range between 0.42 and 0.60, all $P < 0.01$). A correlation table and further descriptive statistics are provided in Supplementary Table 2.

To compare the views of the respondents on geoengineering with their views on conventional mitigation, participants were also asked about the importance of negotiating emission reduction targets (global and sectoral), land-use change, adaptation and technology transfer. The results (Fig. 2) show that the climate experts, similar to other populations[26,29,31], prefer conventional mitigation and adaptation over geoengineering. The distribution of answers for geoengineering shows significantly lower support than the distribution of answers for all other issues (Pearson χ^2_4 test, all $P < 0.01$; Supplementary Table 3).

A comparison of the views of our sample with recently elicited opinions of the US population indicates that the climate experts are more sceptical about geoengineering. Whereas the survey by Mahajan, Tingley and Wagner[25] found that 81% of their respondents support research in solar geoengineering, only half of our respondents support more investment into geoengineering research. In addition, 67% of the surveyed US population support the use of solar geoengineering, whereas only half of our respondents support its use even when limited to an emergency response.

Our main regression analyses are based on binary probit models. To this end, we define a binary variable 'supportive', which is set to 1 if an individual provided a more supportive assessment of geoengineering and 0 otherwise (see Methods). Respondents who chose the 'I don't know' option are not included in the regression analysis. We opted for this more conservative approach because the respondents who chose the 'I don't know' option cannot be unambiguously assigned to a positive or negative assessment of geoengineering. Including these respondents as not supportive of geoengineering yields similar results (Supplementary Table 4). Individual controls such as age, gender, training and employer organization are included in all regression analyses but are not shown in the tables to save space. Expectations of respondents about global climate change impacts, their expectations about current and future mitigation efforts and CO_2 per capita in the respondents' home country are included as explanatory variables. To account for region-specific climate change impacts, we include either respondents' expectations about climate change impacts in their home country or the BHM estimation of the impacts in that country. Because of correlations between current gross domestic product (GDP) per capita and future climate change impacts, we show regression results with and without current GDP per capita. Supplementary Table 2 provides further information on the definitions and the summary statistics of all included variables and Supplementary Table 5 provides the complete regression tables with all controls and model statistics.

Table 2 | Results of binary probit regression testing support for more investment in R&D on geoengineering technologies

Variable	Model			
	(1)	(2)	(3)	(4)
	Supportive	Supportive	Supportive	Supportive
Percentage loss in GDP in 2100	0.36***	0.23***		
	(5.50)	(2.85)		
Percentage gain in GDP in 2100	−0.00	0.01		
	(−0.15)	(0.33)		
Expect severe home country damages (d)			0.25***	0.18***
			(5.05)	(3.53)
GDP per capita		−0.05***		−0.07***
		(−2.99)		(−4.90)
Expect severe global damages (d)	−0.09**	−0.09**	−0.19***	−0.17***
	(−2.25)	(−2.18)	(−4.17)	(−3.82)
CO_2 per capita	1.21	11.75**	−2.11	15.71***
	(0.30)	(2.16)	(−0.50)	(2.73)
Optimistic about GHG reductions	0.05	0.05	0.06	0.08*
	(1.33)	(1.44)	(1.49)	(1.95)
Optimistic about INDCs	0.13***	0.12***	0.16***	0.13***
	(3.64)	(3.35)	(4.02)	(3.46)
IPCC (d)	−0.21***	−0.19***	−0.22***	−0.18***
	(−3.61)	(−3.24)	(−3.60)	(−3.04)
Controls included	Yes	Yes	Yes	Yes
Observations	477	476	432	431

The numbers show binary probit estimations of average marginal effects (discrete effects for dummy variables) and *z* values in parentheses. The models are estimated with maximum likelihood, using heteroscedasticity robust standard errors. The stochastic component in the models is assumed to be normally distributed. The dependent variable is a dummy, taking the value of 1 if an individual response is categorized as supportive of geoengineering and 0 otherwise. Models (1) and (2) account for region-specific climate change impacts using the BHM estimations whereas models (3) and (4) use expectations of respondents. Models (2) and (4) additionally control for GDP per capita in the home country of the respondent. *$P<0.10$, **$P<0.05$, ***$P<0.01$. d, dummy variable. Variables included as controls but not shown: gender, age, training and employer organization.

The main regression results are shown in Tables 1–3. We show separate regression analyses for each survey item because the three questions that we use for the assessment of geoengineering are quite different in content and have also been studied separately in the literature. Table 1 shows whether the opinions of respondents on whether geoengineering should be included in the international climate negotiations are influenced by the explanatory variables. Respondents who expect severe global climate change damages are less likely to support the inclusion of geoengineering in the climate negotiations than respondents with less pessimistic expectations ($P<0.01$ in all specifications). Similarly, respondents who have pessimistic expectations about the effectiveness of the current pledge approach are less likely to support the inclusion than respondents with more optimistic expectations ($P<0.05$ in two specifications). If GDP per capita in the home country is not included, we find that respondents from countries that are predicted to suffer high climate change damages are more likely to support the inclusion of geoengineering in the negotiations ($P<0.01$). In line with this result, respondents who expect high climate change damages in their home country are more likely to support the inclusion ($P<0.05$). The significance of these two differences disappears if GDP per capita is included. The dominant effect in this case is that respondents from richer countries are less likely to support the inclusion than respondents from poorer countries. Finally, respondents who prefer a broad approach of the climate negotiations support the inclusion of geoengineering more than respondents who prefer a narrow approach ($P<0.01$ in all specifications).

Table 2 shows the regression results for the support of the respondents for more investment directed to R&D on geoengineering technologies. Respondents who expect severe global climate change damages are less likely to support more investment in geoengineering technologies than respondents with less pessimistic expectations ($P<0.05$ or $P<0.01$). Similarly, respondents who are pessimistic about the current pledge approach are less likely to support more investment than more optimistic respondents ($P<0.01$). Considering regional climate change impacts, we find that both measures of vulnerability—the BHM estimations of future climate change impacts and respondents' own expectations about their home country—increase the support for more geoengineering investments significantly ($P<0.01$). This is independent of whether GDP per capita is included or not. As above, a higher GDP per capita decreases the support for geoengineering ($P<0.01$).

Table 3 shows regression results for the support of the respondents of large-scale deployment of geoengineering in case of an approaching climate emergency. Negative expectations about global climate change impacts tend to reduce the support of geoengineering as above, although the difference is not significant at the 1% or 5% level. Optimism about the current pledge approach does not have a significant effect. Respondents who are optimistic that countries will reduce their emissions even in the absence of a global agreement are more likely to support deployment of geoengineering than more pessimistic respondents ($P<0.05$ in two specifications). Respondents from countries for which severe climate change damages are predicted are more likely to support deployment of geoengineering.

Table 3 | Results of binary probit regression testing support for large-scale use of geoengineering in case of a climate emergency

Variable	Model			
	(1)	(2)	(3)	(4)
	Supportive	Supportive	Supportive	Supportive
Percentage loss in GDP in 2100	0.19**	0.18*		
	(2.55)	(1.89)		
Percentage gain in GDP in 2100	0.04	0.04		
	(1.23)	(1.28)		
Expect severe home country damages (d)			0.11**	0.10*
			(2.06)	(1.65)
GDP per capita		−0.01		−0.01
		(−0.37)		(−0.74)
Expect severe global damages (d)	−0.04	−0.04	−0.09*	−0.09*
	(−0.86)	(−0.91)	(−1.83)	(−1.76)
CO_2 per capita	−2.15	−0.53	−3.58	−0.69
	(−0.49)	(−0.09)	(−0.83)	(−0.12)
Optimistic about GHG reductions	0.08*	0.08*	0.09**	0.09**
	(1.91)	(1.89)	(2.07)	(2.07)
Optimistic about INDCs	0.04	0.04	0.07	0.06
	(0.90)	(0.86)	(1.50)	(1.37)
IPCC (d)	−0.18***	−0.18***	−0.19***	−0.19***
	(−2.81)	(−2.74)	(−2.84)	(−2.72)
Controls included	Yes	Yes	Yes	Yes
Observations	426	425	385	384

The numbers show binary probit estimations of average marginal effects (discrete effects for dummy variables) and *z* values in parentheses. The models are estimated with maximum likelihood, using heteroscedasticity robust standard errors. The stochastic component in the models is assumed to be normally distributed. The dependent variable is a dummy, taking the value of 1 if an individual response is categorized as supportive of geoengineering and 0 otherwise. Models (1) and (2) account for region-specific climate change impacts using the BHM estimations whereas models (3) and (4) use expectations of respondents. Models (2) and (4) additionally control for GDP per capita in the home country of the respondent. $^{*}P<0.10$, $^{**}P<0.05$, $^{***}P<0.01$. d, dummy variable. Variables included as controls but not shown: gender, age, training and employer organization.

The same is true when we consider respondents' expectations about their home country ($P<0.05$ in two specifications).

These results show that respondents who expect severe global damages of climate change and respondents who are sceptical about current mitigation efforts are more opposed to geoengineering than more optimistic respondents. By contrast, severe climate change damages in their home country, either predicted by the BHM study or by respondents themselves, increase support for geoengineering. The difference between the global and home country perspective is illustrated in Fig. 3. Robustness analyses show that our main results hold if we use a combined index of the three dependent variables (Supplementary Table 6), if an ordered probit model is used instead of a binary model (Supplementary Table 7), for alternative measures of climate change impacts (Supplementary Table 8) and if we run separate estimations for the UNFCCC and IPCC samples (Supplementary Table 9).

A possible reason for the difference between the global and home country perspective is that respondents extrapolate, consciously or unconsciously, from generally difficult governance at the global level and easier governance at the national level. If this were the case, we would expect the difference between the global and home country perspective to be particularly large when respondents are asked about the deployment of geoengineering, because this is when governance matters the most. However, as shown in Fig. 3, the difference is smaller for the deployment of geoengineering than for the other two issues. We would also expect that the difference between the global and home country perspective is particularly large for respondents from countries with effective governance systems. However, additional regression analyses that include the governance effectiveness index provided by the World Bank do not show any evidence that an effective governance system in the respondents' home country increases the difference between the global and home country perspective (Supplementary Fig. 1). Extrapolation from global and national governance therefore is unlikely to be a driver of these results.

The regression results also show how other personal characteristics of the respondents influence their views on geoengineering (Supplementary Table 5). A robust finding is that respondents from the IPCC sample are more opposed to geoengineering than respondents from the UNFCCC sample. Respondents with a degree in natural sciences are more likely to oppose geoengineering than respondents with other backgrounds (mostly economics or business administration, engineering, political sciences or law). Notably, this is not only true for deployment of geoengineering but also for research on geoengineering and the inclusion of geoengineering in the climate negotiations. A possible explanation for this is that individuals who are more engaged in the difficulties of reducing emissions are more open to geoengineering than individuals who focus more on the physical impacts of climate change. Another possible explanation is that IPCC and natural scientists are more sceptical about the effectiveness of geoengineering or more concerned about the potential risks. Although intuitive, our data do not allow us to investigate these possibilities further.

Discussion

Solar geoengineering could be used to limit the increase in temperature that is responsible for a large part of expected climate change

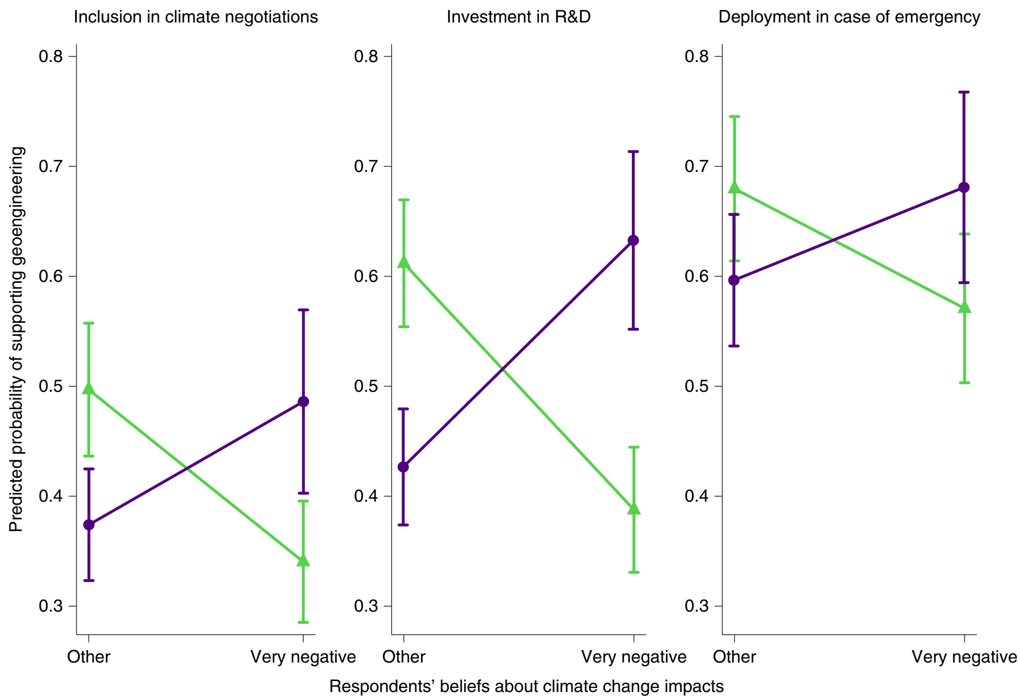

Fig. 3 | Predicted probability of supporting geoengineering depending on the beliefs of respondents about climate change impacts. The probability of supporting geoengineering predicted by the binary probit models shown in Tables 1–3. The green lines (rectangular markers) show the difference between respondents who expect very negative global consequences of climate change and other respondents. The purple lines (circular markers) show the difference between respondents who expect very negative consequences of climate change for their home country and other respondents. The vertical lines show the 95% confidence interval. Number of observations (from left to right): $n = 447$, $n = 432$ and $n = 385$.

damages. Cost–benefit analyses show that the incentives to deploy geoengineering become stronger with higher CO_2 emissions and expected climate change damages[39–42]. Many people, however, reject this argument on moral grounds[27,44]. The Australian philosopher Clive Hamilton, for instance, writes: "merely by choosing to engineer the climate instead of cutting emissions we succumb to moral failure"[27]. From this perspective, geoengineering is not a legitimate solution to address climate change but rather another risky experiment with unforeseeable and potentially irreversible consequences. Higher climate change damages do not justify the use of geoengineering; on the contrary, they warn against further experimentation with the planet and stress the moral obligation of curbing emissions. Our results suggest that geoengineering represents a moral dilemma for the surveyed climate experts. At the global level, we find that respondents indeed oppose geoengineering more strongly the more they are concerned about severe climate change damages and continued rise of global emissions. However, at a more personal level, they are more open to geoengineering the more they are concerned about high damages of climate change in their home country. This latter view is what we would expect from a rational cost–benefit analysis in which geoengineering generally is considered to be a legitimate solution as long as the risks and side effects are not too high[39–42].

Solar geoengineering poses different challenges for governance than conventional climate change mitigation efforts[45]. Many questions regarding geoengineering governance have not been answered yet, including who should decide whether, under which conditions and to what extend geoengineering should be deployed and which side effects are acceptable and which are not. Our research shows that the opinions about the deployment of geoengineering are positively correlated with the opinions about research on geoengineering technologies and the integration of the issue in the UNFCCC process. Thus, individuals who oppose the deployment of geoengineering also tend to oppose research on geoengineering and putting the topic on the agenda. These results were not necessarily expected. For example, if the experts opposed the use of geoengineering because of the potential side effects and uncertainty, they should support more investment in research. If the experts opposed geoengineering because of the involved governance challenges, they should be in favour of including the issue in the UNFCCC process. Bringing geoengineering into the UNFCCC process would allow the experts to be actively involved in the implementation of common rules and constraints[45,46]. The tendency of the experts to be concerned, or not concerned, about all three aspects—deployment of geoengineering, research and development, and including the topic in the negotiations—indicates that for many experts geoengineering is a moral issue. The implication for policymakers, scientists and other actors who wish to shape the debate about geoengineering is that moral concerns beyond costs and benefits must be addressed. All the same, our study suggests that the climate experts' support for geoengineering will increase over time, as more regions are adversely affected and more experts observe or expect damages in their home country.

Online content

Any methods, additional references, Nature Research reporting summaries, source data, statements of code and data availability and associated accession codes are available at https://doi.org/10.1038/s41558-019-0564-z.

Received: 4 March 2019; Accepted: 25 July 2019;
Published online: 02 September 2019

References

1. Rogelj, J. et al. Paris Agreement climate proposals need a boost to keep warming well below 2 °C. *Nature* **534**, 631–639 (2016).

2. Crutzen, P. J. Albedo enhancement by stratospheric sulfur injections. A contribution to resolve a policy dilemma?. *Climatic Change* **77**, 211–220 (2006).
3. Wigley, T. M. L. A combined mitigation/geoengineering approach to climate stabilization. *Science* **314**, 452–454 (2006).
4. *Geoengineering the Climate: Science, Governance and Uncertainty* (The Royal Society, 2009).
5. Victor, D. G., Morgan, M. G., Apt, J., Steinbrunner, J. & Ricke, K. The geoengineering option: a last resort against global warming? *Foreign Aff.* **88**, 64–76 (2009).
6. Robock, A. Whither geoengineering? *Science* **320**, 1166–1167 (2008).
7. Tilmes, S., Müller, R. & Salawitch, R. The sensitivity of polar ozone depletion to proposed geoengineering schemes. *Science* **320**, 1201–1204 (2008).
8. Tilmes, S., Garcia, R. R., Kinnison, D. E., Gettelman, A. & Rasch, P. J. Impact of geoengineered aerosols on the troposphere and stratosphere. *J. Geophys. Res.* **114**, D12305 (2009).
9. Haywood, J. M., Jones, A. & Jones, G. S. The impact of volcanic eruptions in the period 2000-2013 on global mean temperature trends evaluated in the HadGEM2-ES climate model. *Atmos. Sci. Lett.* **15**, 92–96 (2014).
10. Irvine, P. J., Sriver, R. L. & Keller, K. Tension between reducing sea-level rise and global warming through solar-radiation management. *Nat. Clim. Change* **2**, 97–100 (2012).
11. IPCC *Climate Change 2013: The Physical Science Basis* (eds Stocker, T. F. et al.) (Cambridge Univ. Press, 2013).
12. Tollefson, J. Sucking carbon dioxide from air is cheaper than scientists thought. *Nature* **558**, 173 (2018).
13. Boucher, O. et al. Reversibility in an Earth System model in response to CO_2 concentration changes. *Environ. Res. Lett.* **7**, 024013 (2012).
14. Scott, V., Haszeldine, R. S., Tett, S. F. B. & Oschlies, A. Fossil fuels in a trillion tonne world. *Nat. Clim. Change* **5**, 419–423 (2015).
15. Azar, C., Lindgren, K., Larson, E. & Möllersten, K. Carbon capture and storage from fossil fuels and biomass—costs and potential role in stabilizing the atmosphere. *Climatic Change* **74**, 47–79 (2006).
16. Tollefson, J. Geoengineering debate shifts to UN environment assembly. *Nature* **567**, 156 (2019).
17. Robock, A., Marquardt, A., Kravitz, B. & Stenchikov, G. Benefits, risks, and costs of stratospheric geoengineering. *Geophys. Res. Lett.* **36**, L19703 (2009).
18. McClellan, J., Keith, D. W. & Apt, J. Cost analysis of stratospheric albedo modification delivery systems. *Environ. Res. Lett.* **7**, 034019 (2012).
19. Vaughan, N. E. & Lenton, T. M. A review of climate geoengineering proposals. *Climatic Change* **109**, 745–790 (2011).
20. IPCC *Global Warming of 1.5 °C* (World Meteorological Organization, 2018).
21. Corner, A., Parkhill, K., Pidgeon, N. & Vaughan, N. E. Messing with nature? Exploring public perceptions of geoengineering in the UK. *Glob. Environ. Change* **23**, 938–947 (2013).
22. Winickoff, D. E., Flegal, J. A. & Asrat, A. Engaging the Global South on climate engineering research. *Nat. Clim. Change* **5**, 627–634 (2015).
23. Pidgeon, N., Parkhill, K., Corner, A. & Vaughan, N. Deliberating stratospheric aerosols for climate geoengineering and the SPICE project. *Nat. Clim. Change* **3**, 451–457 (2013).
24. Corner, A. & Pidgeon, N. Geoengineering, climate change scepticism and the 'moral hazard' argument: an experimental study of UK public perceptions. *Phil. Trans. R. Soc. A* **372**, 20140063 (2014).
25. Mahajan, A., Tingley, D. & Wagner, G. Fast, cheap, and imperfect? US public opinion about solar geoengineering. *Env. Polit.* **28**, 523–543 (2019).
26. Bostrom, A. et al. Causal thinking and support for climate change policies: international survey findings. *Glob. Environ. Change* **22**, 210–222 (2012).
27. Hamilton, C. *Earthmasters: The Dawn of the Age of Climate Engineering* (Yale Univ. Press, 2013).
28. Anshelm, J. & Hansson, A. Battling Promethean dreams and Trojan horses. Revealing the critical discourses of geoengineering. *Energy Res. Soc. Sci.* **2**, 135–144 (2014).
29. Bellamy, R., Chilvers, J., Vaughan, N. E. & Lenton, T. M. 'Opening up' geoengineering appraisal. Multi-criteria mapping of options for tackling climate change. *Glob. Environ. Change* **23**, 926–937 (2013).
30. Scholte, S., Vasileiadou, E. & Petersen, A. C. Opening up the societal debate on climate engineering. How newspaper frames are changing. *J. Integr. Environ. Sci.* **10**, 1–16 (2013).
31. Burns, E. T. et al. What do people think when they think about solar geoengineering? A review of empirical social science literature, and prospects for future research. *Earths Futur.* **4**, 536–542 (2016).
32. Corner, A., Pidgeon, N. & Parkhill, K. Perceptions of geoengineering. Public attitudes, stakeholder perspectives, and the challenge of 'upstream' engagement. *WIREs. Clim. Change* **3**, 451–466 (2012).
33. Wright, M. J., Teagle, D. A. H. & Feetham, P. M. A quantitative evaluation of the public response to climate engineering. *Nat. Clim. Change* **4**, 106–110 (2014).
34. Corner, A. & Pidgeon, N. Like artificial trees? The effect of framing by natural analogy on public perceptions of geoengineering. *Climatic Change* **130**, 425–438 (2015).
35. Luokkanen, M., Huttunen, S. & Hildén, M. Geoengineering, news media and metaphors: framing the controversial. *Public Underst. Sci.* **23**, 966–981 (2014).
36. Scheer, D. & Renn, O. Public perception of geoengineering and its consequences for public debate. *Climatic Change* **125**, 305–318 (2014).
37. Pidgeon, N. et al. Exploring early public responses to geoengineering. *Phil. Trans. R. Soc. A* **370**, 4176–4196 (2012).
38. Merk, C., Pönitzsch, G., Kniebes, C., Rehdanz, K. & Schmidt, U. Exploring public perceptions of stratospheric sulfate injection. *Climatic Change* **130**, 299–312 (2015).
39. Goes, M., Tuana, N. & Keller, K. The economics (or lack thereof) of aerosol geoengineering. *Clim. Change* **109**, 719–744 (2011).
40. Bahn, O., Chesney, M., Gheyssens, J., Knutti, R. & Pana, A. C. Is there room for geoengineering in the optimal climate policy mix? *Environ. Sci. Policy* **48**, 67–76 (2015).
41. Bickel, J. E. & Agrawal, S. Reexamining the economics of aerosol geoengineering. *Clim. Change* **119**, 993–1006 (2013).
42. Heutel, G., Moreno-Cruz, J. & Shayegh, S. Solar geoengineering, uncertainty, and the price of carbon. *J. Environ. Econ. Manage.* **87**, 24–41 (2018).
43. Burke, M., Hsiang, S. M. & Miguel, E. Global non-linear effect of temperature on economic production. *Nature* **527**, 235–239 (2015).
44. Gardiner, S. (ed.) in *Climate Ethics* (eds Gardiner, S. M. et al.) 284–312 (Oxford Univ. Press, 2010).
45. Bodansky, D. The who, what, and wherefore of geoengineering governance. *Clim. Change* **121**, 539–551 (2013).
46. Barrett, S. The incredible economics of geoengineering. *Environ. Resour. Econ.* **39**, 45–54 (2008).

Acknowledgements

The work was financially supported by the European Union Horizon 2020 Program, Action ERC-2014-STG, Project HUCO, grant number 636746.

Author contributions

A.D. and S.Z. contributed equally to this work.

Competing interests

The authors declare no competing interests.

Additional information

Supplementary information is available for this paper at https://doi.org/10.1038/s41558-019-0564-z.

Reprints and permissions information is available at www.nature.com/reprints.

Correspondence and requests for materials should be addressed to A.D.

Peer review information: *Nature Climate Change* thanks Karen Parkhill, Michael Siegrist and Gernot Wagner for their contribution to the peer review of this work.

Publisher's note: Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Methods

Sample. Invitations to take part in the survey were sent out by email in the run-up to the twenty-first Conference of Parties (COP 21) in Paris. The contacts were taken from two sources. First, for the UNFCCC sample, invitations were sent to individuals listed as party member in at least one of the COPs since COP 16 in 2010. The email addresses were taken from previous studies or by searching the internet. The UNFCCC provides participation lists that distinguish between 'parties' and 'observer organizations'. As we are interested in the opinions of negotiators, and not observers, we only invited people who were listed at least once as a party. Individuals who attended the COPs only as an observer (and never as a party) were not included. Second, for the IPCC sample, invitations were sent to individuals listed as authors or reviewers of the Fifth Assessment Report. The list is available on the IPCC website and the email addresses were obtained by searching the internet. In the regression analyses, we always control for whether an individual is from the UNFCCC sample or the IPCC sample. Regression analyses for each sample separately are provided in Supplementary Table 9.

Separated by source, we reached out to 8,763 individuals from the UNFCCC lists and 900 individuals from the IPCC list. A total of 723 individuals from 153 countries took part in the survey (509 from the UNFCCC lists and 214 from the IPCC list). The number of observations in the regression analyses is lower because some respondents did not answer all questions included as control variables and we left out all respondents who chose the 'I don't know' option when assessing geoengineering. The response rate of 7% (6% UNFCCC and 24% IPCC) is not high but comparable to previous studies using similar samples[47–52]. It should also be noted that the response rate of 7% is a very conservative estimation as it refers to all emails that were sent out and did not immediately bounce back. We do not know, and have no way to find out, how many of these emails went to the spam folder, arrived at inactive email accounts, or were never opened for other reasons. If we related the number of respondents to the number of people who were invited and verifiably opened the link to the survey, the response rate would be 63% (59% UNFCCC and 77% IPCC).

Because of the low response rate, we conducted two different non-response analyses for the UNFCCC sample. First, we compared the regional distribution between individuals who completed the survey (respondents) and individuals who were contacted but did not complete the survey (non-respondents). Of the UNFCCC participants who completed the survey, 26% were from Europe, 24% from Africa, 20% from Asia, 13% from North America, 12% from South America and 5% from Australia/Oceania. The respective frequencies for the contacted persons who did not complete the survey were 22%, 27%, 24%, 10%, 13% and 4%. These proportions are based on delegation country and not nationalities, as delegation country is the only available information for non-respondents. The comparison of the regional distribution between respondents and non-respondents shows that the distributions do not significantly differ from each other (Pearson χ^2 test, $\chi^2_5=2.95$, $P>0.1$). We also find that the distribution of the respondents is very similar to the regional distribution of the participants in recent COPs. Of the parties who attended COPs 16–20, on average, 21% were from Europe, 27% from Africa, 25% from Asia, 9% from North America, 13% from South America and 4% from Australia/Oceania. Second, we compared the answers of respondents and individuals who started the survey but did not finish it (dropouts). We could only do these comparisons for questions that were answered by a sufficient number of dropouts; these questions were mainly from the first part of the survey. Depending on the questions, the number of dropouts that could be used for comparison ranged from 48 to 91. Depending on the type of question, we used Fisher's exact tests or t-tests. We found that for 19 out of 21 questions the answers were not significantly different between respondents and dropouts ($P>0.1$). These comparisons thus do not point to a selection bias in the data, although, of course, we cannot completely rule this possibility out.

As our main interest in this paper is the assessment of geoengineering, it is more important that the respondents do not have biased opinions about geoengineering rather than that they are representative of the overall population. In other words, the assessment of geoengineering by the respondents should not systematically differ from the assessment by non-respondents. Before we provide evidence regarding this claim, note that the invitation to take part in the survey did not mention geoengineering and the survey did not start with questions about geoengineering. Of all people who started the survey and dropped out at some point, 93% dropped out before they could see the first question about geoengineering. To compare the opinions about geoengineering between our respondents and others, we use the survey data collected in previously published studies by Kesternich, Löschel and Ziegler (KLZ)[49,53]. The KLZ survey was conducted in 2012 with officially listed participants of COP 16 (Cancún) and COP 17 (Durban). This sample is particularly useful for comparison, because the survey included 24 items that we also included in our questionnaire (10 socio-demographic characteristics, 14 items on expected global and regional climate change consequences, the willingness of countries to reduce emissions without global agreement, and the importance of including emission-reduction targets, technology transfer, adaptation, land-use change and geoengineering in climate negotiations). Although the KLZ survey included one item on geoengineering, their main interest was on burden sharing rules and the design of minimum participation thresholds in climate treaties (the resulting publications do not mention geoengineering). Because of the overlap in questions, we excluded the respondents of the KLZ survey from our survey (by not inviting them), which makes them a good reference group. The comparison of the KLZ sample and our sample shows some small differences that can be explained by changes over time and the fact that we drew our sample from more COPs. Our sample is more balanced with relatively more women and more respondents from South America and North America. Our sample is slightly more pessimistic about climate change damages in the future and, at the same time, slightly more optimistic about emission reductions in the United States, Europe and China. Most importantly, opinions about the importance of including geoengineering in the climate negotiations do not significantly differ between the two samples. The average answer to this question is almost the same (2.47 in the KLZ study versus 2.45 for our sample) and the same is true for the standard deviation (1.01 versus 1.02). The P value is far from any conventional significance levels ($P=0.77$).

Questionnaire and empirical approach. The survey was conducted online and comprised several parts. All survey questions used in this research can be found in the Supplementary Methods. Definitions and summary statistics of the dependent and explanatory variables can be found in the Supplementary Table 2.

After obtaining the respondents' consent to participate, the first part assessed the consequences of climate change for future living conditions and the importance of various measures to combat climate change. The second part was about the effectiveness of current and future climate change mitigation efforts. The third part of the survey contained questions about the personal background of the participants, such as gender, age, nationality, the field in which they had obtained their highest degree of training and the type of organization for which they work. The questions about geoengineering were included in the first part of the survey. Participants were asked about the importance of including geoengineering in international climate negotiations, the need to direct more investment to research and development on geoengineering technologies, and deployment of geoengineering in the event of an approaching climate emergency. All three assessments were elicited by means of a Likert-type scale with four possible answer categories that ranked the support of the respondents from low to high, with one additional 'I don't know' option. We did not provide a description or definition of geoengineering, so as to not bias the answers, but explicitly mentioned solar radiation management.

Respondents' assessments of geoengineering were used as dependent variables in the regression analyses. In the binary probit models, the dependent variables are constructed as a dummy that takes the value of 1 if the respondent chose one of the two more supportive answer categories and 0 otherwise. We also estimated an ordered probit model to test the robustness of the results with respect to the regression model. The results of the ordered probit model are generally very close to the binary probit results (Supplementary Table 7).

Three types of information were included as explanatory variables: specific information about the respondents and their home country, expectations about the effectiveness of current and future climate change mitigation efforts, and expectations about climate change impacts. Estimations of regional climate change impacts were taken from the BHM study. This study estimates region-specific changes in GDP per capita due to temperature increase from unmitigated climate change compared to a counterfactual situation without climate change[43]. Using two scenarios from the IPCC (the business-as-usual Representative Concentration Pathway (RCP)8.5 and the Shared Socioeconomic Pathway (SSP)5, which assumes fast economic growth and high energy demand), the study provides comparisons of regional GDP per capita with and without climate change in 2100. We use this percentage difference in GDP per capita, separated as either loss or gain, as explanatory variables in our regression analyses to take vulnerability of the home country of the respondents into account.

Home country refers to a person's citizenship for the IPCC sample. For the UNFCCC sample, we can take either a person's citizenship as home country or the country that he or she represents in the negotiations. We decided to show regression analyses based on delegation country in the main paper and regression analyses based on citizenship in the Supplementary Table 10. As most negotiators represent their own country in the negotiations (93% of negotiators in our data), the results are very similar. We also provide additional regression analyses in which regional vulnerability is measured by the 2015 ND-GAIN index (Supplementary Table 8). This index is compiled by the Notre Dame Global Adaptation Initiative and combines different measures of vulnerability to climate change with measures of adaptive capacity. Using this index, instead of the estimations by the BHM study, yields very similar results. We also tested the suitability of more recent and fine-grained climate change data provided by Ricke, Drouet, Caldeira and Tavoni (RDCT)[54]. This study provides country-specific estimates of the social cost of carbon discounted from the year 2200. The correlations between the BHM estimates and the RDCT estimates are relatively weak, which can be attributed to the existing differences between the two datasets. There is no significant correlation between the RDCT estimates and the expectations of our respondents ($r=0.03$, $P=0.51$, $n=636$). The reason for this is arguably that the question that we used to elicit expectations ('How would you assess the consequences of climate change on future living conditions up to 2100 in your home country?') is closer to the BHM estimates than the RDCT estimates. The more fine-grained results of the RDCT study apparently do not outweigh this difference.

Furthermore, the regression analyses include CO_2 emissions per capita in the home country to account for the dependence of each country on fossil fuels and GDP per capita in the home country to account for adaptive capacity. Again, for the UNFCCC sample, we can take either the country that a person represents in the negotiations (shown in the main paper) or his/her citizenship (Supplementary Table 10), both of which yield similar results.

All other variables used in the regression analyses were elicited in the survey. The subjective expectations of the respondents about climate change impacts were elicited by asking them to estimate the consequences of climate change on future living conditions up to 2100 both globally and for their home country. The assessments were elicited by means of a Likert-type scale with four answer categories ranging from 'very negative' to 'positive' and an 'I don't know' option. The variable for 'expect severe global damages' is constructed as a dummy variable that takes the value of 1 if the respondent expects very negative consequences of climate change on future global living conditions up to 2100 and 0 otherwise. The variable for 'expect severe home country damages' is constructed in precisely the same way with the only difference that respondents are asked to assess the consequences for the home country. Despite the similarity, the regression analyses show that the two variables affect respondents' assessment of geoengineering very differently. Including an interaction term for the expectations of respondents on a global scale and for their home country in the regression analyses yields very similar results and the interaction term is never significant. This indicates that the positive effect of the expectations for their home country does not depend on the expectations of respondents on a global scale and vice versa.

To account for the expectations of respondents about current and future climate change mitigation efforts, we constructed two different variables. First, participants were asked to indicate on a four-point Likert-type scale to which degree they think that certain countries or groups of countries would reduce emissions relative to business as usual independent of an international climate agreement. The list of countries included the major emitters China, United States and the EU. The answers were averaged for each respondent and form the variable 'optimistic about GHG reductions' (Cronbach's $\alpha = 0.71$). Second, participants were asked about their expectations about the pledges made in the context of the Paris Agreement. Specifically, they were asked how confident they were that (a) the current INDCs in aggregate are consistent with the 2 °C target; (b) countries will submit more ambitious INDCs in the future; and (c) future INDCs in aggregate are consistent with the 2 °C target. Answers were elicited on a four-point Likert-type scale. The variable 'optimistic about INDCs' was constructed by taking the respondent's average level of confidence stated in these three questions ($\alpha = 0.78$). For the question whether geoengineering should be included in the international climate negotiations, we additionally included the explanatory variable 'negotiation scope', which was constructed by taking the respondents' average level of support regarding the inclusion of different issues in the climate negotiations. For each of the following issues we asked the respondents to state on a four-point Likert-type scale how important it is to include the issue in the climate negotiations: (a) quantitative reduction targets for global GHG emissions; (b) quantitative reduction targets for sectoral GHG emissions; (c) R&D and technology transfer; (d) land-use change and reforestation; and (e) adaptation measures. Combining the average support for each issue, the index yields a high value if a respondent supports a broad negotiation approach—that is, the inclusion of many issues in the negotiations—and a low value if a respondent supports a narrow approach—that is, the inclusion of only a few issues in the negotiations ($\alpha = 0.67$).

In all estimations, we control for respondents' gender, age, training, employer organization, and whether the respondent belongs to the IPCC sample or the UNFCCC sample.

Ethical statement. This research was conducted in full compliance with the ethical requirements of the European Research Council.

Reporting Summary. Further information on research design is available in the Nature Research Reporting Summary linked to this article.

Data availability

The dataset necessary to reproduce the findings of this study is publicly available at https://doi.org/10.5281/zenodo.3341559. The data used from BHM can be accessed at https://web.stanford.edu/~mburke/climate/data.html. The data for the ND-GAIN index can be accessed at https://gain.nd.edu/our-work/country-index/. Data for GDP per capita in 2015 are from the World Bank's Development Indicators and are available at https://databank.worldbank.org/data/source/world-development-indicators. Data for CO_2 per capita in 2015 are from the European Commission and are available at http://edgar.jrc.ec.europa.eu/overview.php?v=CO2andGHG1970-2016.

References

47. Lange, A., Vogt, C. & Ziegler, A. On the importance of equity in international climate policy. An empirical analysis. *Energy Econ.* **29**, 545–562 (2007).
48. Lange, A., Löschel, A., Vogt, C. & Ziegler, A. On the self-interested use of equity in international climate negotiations. *Eur. Econ. Rev.* **54**, 359–375 (2010).
49. Kesternich, M. Minimum participation rules in international environmental agreements. Empirical evidence from a survey among delegates in international climate negotiations. *Appl. Econ.* **48**, 1047–1065 (2016).
50. Karlsson, C., Parker, C., Hjerpe, M. & Linnér, B.-O. Looking for leaders: perceptions of climate change leadership among climate change negotiation participants. *Glob. Environ. Polit.* **11**, 89–107 (2011).
51. Dannenberg, A., Sturm, B. & Vogt, C. Do equity preferences matter for climate negotiators? An experimental investigation. *Environ. Resour. Econ.* **47**, 91–109 (2010).
52. Dannenberg, A., Zitzelsberger, S. & Tavoni, A. Climate negotiators' and scientists' assessments of the climate negotiations. *Nat. Clim. Change* **7**, 437–442 (2017).
53. Kesternich, M., Löschel, A. & Ziegler, A. *Negotiating Weights for Burden Sharing Rules Among Heterogeneous Parties: Empirical Evidence from a Survey Among Delegates in International Climate Negotiations* Discussion Paper No. 14-031 (ZEW– Centre for European Economic Research, 2014).
54. Ricke, K., Drouet, L., Caldeira, K. & Tavoni, M. Country-level social cost of carbon. *Nat. Clim. Change* **8**, 895–900 (2018).

naturereserch

Corresponding author(s): Dannenberg, Astrid

Last updated by author(s): Jul 18, 2019

Reporting Summary

Nature Research wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Research policies, see Authors & Referees and the Editorial Policy Checklist.

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a	Confirmed	
☐	☒	The exact sample size (n) for each experimental group/condition, given as a discrete number and unit of measurement
☐	☒	A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
☐	☒	The statistical test(s) used AND whether they are one- or two-sided *Only common tests should be described solely by name; describe more complex techniques in the Methods section.*
☐	☒	A description of all covariates tested
☐	☒	A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
☐	☒	A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
☐	☒	For null hypothesis testing, the test statistic (e.g. F, t, r) with confidence intervals, effect sizes, degrees of freedom and P value noted *Give P values as exact values whenever suitable.*
☒	☐	For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☒	☐	For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☐	☒	Estimates of effect sizes (e.g. Cohen's d, Pearson's r), indicating how they were calculated

Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	Survey was conducted online with Qualtrics
Data analysis	Stata 14

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors/reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Research guidelines for submitting code & software for further information.

Data

Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A list of figures that have associated raw data
- A description of any restrictions on data availability

Data and code to reproduce the main results (Main Paper and SI) are available at https://doi.org/10.5281/zenodo.3341559 (Open access will be provided after publication)

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☒ Behavioural & social sciences ☐ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Behavioural & social sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	Self-reported survey data enhanced with empirical data, quantitative analysis
Research sample	Country delegates from UNFCCC COPs since 2010 and authors or reviewers of the 5th IPCC Assessment Report
Sampling strategy	No calculation to predetermine sample size was done. The sample is restricted by the availability of contact adresses online and willingness to participate in the survey.
Data collection	Online Qualtrics survey administered via email
Timing	Summer 2015
Data exclusions	Respondents who have not answered the relevant questions for this analysis were dropped.
Non-participation	Overall response rate is 7% (6% in UNFCCC sample and 24% in IPCC sample) based on sent emails (net of bounced emails). If we only consider emails that were verifiably read (i.e. the link to the survey was opened), the response rate is 63% (59% UNFCCC and 77% IPCC).
Randomization	n/a

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study	
☒	☐	Antibodies
☒	☐	Eukaryotic cell lines
☒	☐	Palaeontology
☒	☐	Animals and other organisms
☐	☒	Human research participants
☒	☐	Clinical data

Methods

n/a	Involved in the study	
☒	☐	ChIP-seq
☒	☐	Flow cytometry
☒	☐	MRI-based neuroimaging

Human research participants

Policy information about studies involving human research participants

Population characteristics	70.5% percent male, Mean age 48 years, 29.6% from IPCC sample, 26% from Europe, 24% from Africa, 20% from Asia, 13% from North America, 12% from South America, 5% from Australia/Oceania
Recruitment	Email adresses were researched on the internet (only part of the potential participants adresses could be found) and invitations sent to those adresses with the invitation to particiapte in the survey (self-selection)
Ethics oversight	This research was conducted in full compliance with the ethical requirements of the European Research Council.

Note that full information on the approval of the study protocol must also be provided in the manuscript.